STUDY ON CRUSHED SAND FOR CONCRETE

BY:

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CERTIFICATION

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ABSTRACT

Conventionally concrete is mixture of cement, sand and aggregate. Properties of aggregate affect the strength and quality of concrete; thus fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural sand. Nowadays the development of infrastructures is becoming the number one priority in the world, particularly in the developing countries. So there are great demands within the construction industries for natural sand as fine aggregate used in the production of concrete.

This has created a very difficult situation; the cost of natural sand has increased and also there is great fear from environmental list and ecologist that in the future there may be scarce of natural sand and the environment and the ecology will be distorted. Hence, the need to find materials which are affordable and available to replace natural sand in the production of concrete. One of these materials is crushed sand and this research studies its suitability as a fine aggregate.

Crushed sand is a term used for aggregate materials less than 4.75mm and which are produced from quires stone crushed. Which is specially prepared so as to get smooth textured, well graded particles. Crushed stone sand is cheaply and easily available in local areas. [1]

Conducted to study the influence that crushed sand has in bulking of sand, compressive strength of concrete, workability and Water absorption to compare the cost of different concrete mix and to assess the prospects of using crushed sand as replacement of natural sand in Ethiopia.

Initially, different natural and crushed sand samples to be used in the concrete mixes were collected and their experimental studied. Concrete mixes having three mix proportions (were prepared for 20, 25 and 30 MPa) with natural sand and crushed sand. The mix is twenty-seven cubic cast for compressive strength test and twelve cubic casts for water absorption test. In addition, comparison of costs for selected concrete grade mixes based on the current price of the concrete material collected from Addis Ababa.

In this study beginning of bulking of sand test. Bulking of sand Occurs due to the presence of moisture content in fine aggregate. Bulking of sand increase parentage, the moisture of sand increases and also the volume of sand Moisture content in sand expand the volume of sand. The results of crushed sand less bulking of natural sand. Workability was measured in terms of the slump cone and the results also all grades of concrete mix workability of natural sand great than with crushed sand. Additionally, the experimental results indicated that for all grades of concrete mix proportion, concrete with crushed sand was capable of achieving a higher compressive strength than the natural sand control mix. The water absorption test was conducted on concrete cube age of 7day and 28 days. Results indicated use crushed sand, concrete mix is great when compared to natural sand concrete mix.

The cost comparisons result also have shown that using crushed sand in full replacement to natural sand doesn't cause any significant cost variation. It has been found also that use of crushed sand is more suitable for high strength concrete production. It can therefore, be concluded from the findings of this research that when the availability of natural sand is scarcity in cities where the price of natural sand is as expensive as crushed sand, crushed sand concrete mix is an environmental and better alternative to the use of natural sand. The concrete with crushed sand performed better than concrete with natural sand as the property of crush sand is better than that of natural sand.

Keywords: Crushed sand, bulking of sand, workability, compressive strength, water absorption

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ACRONYMS

ACI: American Concrete Institute 26
CS: Crushed Rock Sand 39
FM: Fines modules 76
NS: Natural Sand 39
OPC: Ordinary Portland Cement 23
w/c: Water to cement ratio 26, 27, 28
wt:weght 81

CHAPTER - I

1. Introduction

1.1. General

Concrete is a composite construction material made primarily with aggregate, cement, and water. There are many formulations of concrete, which provide varying properties, and concrete is the most-used man made product in the world. [1]

Concrete, as the Romans knew it, was a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick. Modern structural concrete differs from Roman concrete in two important details. First, its mix consistency is fluid and homogeneous, allowing it to be poured into forms rather than requiring hand layering together with the placement of aggregate, which, in Roman practice, often consisted of rubble. Second, integral reinforcing steel gives modern concrete assemblies' great strength in tension, whereas Roman concrete could depend only upon the strength of the concrete bonding to resist tension. [2]

Since the discovery of concrete as a revolutionary building material, there has been no looking back for concrete since its modern development. Known as the strongest building material, concrete has found major uses in dams, highways, buildings and many different kinds of building and construction.

The construction industry in Ethiopia is a sector that opens the door for the growth of many additional industries. Building works require high input. For instance, they require different metal products, clay works, and cement and cement products, etc. As such, the growth of these industries will surely follow the growth of the construction industry. Similarly, when the construction and renovation of housing increase, the demand for household furniture increased; thereby, indirectly, opening the door for the growth of the furniture industry. Overall, the construction industry is a sector that can entertain big micro companies, that is widely labor based. All these being take into consideration; the industrial policy of the Federal Democratic Republic of Ethiopia has sought to pay special attention to the construction industry of the country. [3]

One of the important ingredients of conventional concrete is sand. There are different kinds of sand that were used for concrete ingredient. The sand is used from natural existing sand and man-made from stone. Most construction uses natural sand and crushed sand is also used as concrete ingredients which is produced from stone. Using natural sand is expensive and limited since it exists naturally. However, due to the increased use of concrete in almost all types of construction works, the demand of natural sand has been increased. [4]

To meet this demand of the construction industry in Ethiopian, excessive quarrying of sand from riverbeds is taking place causing the depletion of sand resources. The shortage of natural sand due to such heavy demands in growing construction activities have forced to find the suitable substitute. Relative to natural sand and crushed sand the easy ways of getting substitute for natural sand is by crushing natural stone to get crushed sand of desired size and grade. The marketing use of crushed sand will conserve the natural resources for the sustainable development of the concrete in the construction industry.

The source of Crushed sand is a quarry. Crushing rocks, quarry stones or larger aggregate pieces into sand size particles in a factory or quarry manufacture it. It is naturally available and extracted from the riverbeds.

A well-processed Crushed sand as part or full replacement for natural sand is the need of the hour as a long-term solution in the Ethiopian construction industry until other suitable alternatives fine aggregate is developed. Concrete must keep evolving to satisfy the increasing demands of all its users.

1.2 Statement of the Problem

The current trend in the concrete construction industry is an attempt to increase the market demand are large reserves of construction materials. Having the luxury of abundant construction materials is one of the expressions of a great construction industry. Sand is one of the ingredients used in the production of concrete, has become very expensive and also becoming unusual due to the depletion of river beds.

Moreover, the sources of this natural sand are located several hundreds of kilometer away from the city where the majority of the construction industry sector is located. When we look at the current availability and condition of natural sand in Ethiopia, one can easily see that it is an alarming issue. Therefore, it is mandatory to identify alternative sources of sand.

To this regard, one possible alternative material that can be used as a replacement for natural sand is the use of crushed sand. Due to the forecast shortfall in the supply of natural sands and the increased activity in the construction sector, it is apparent that time will come, when crushed sand may play a significant role as an ingredient in concrete production.

In addition to these, studies show that natural sand, which is available today, is deficient in many aspects to be used directly for concrete production.
Some of the factors include: [6]

- It doesn’t contain fine particles, in the required proportion.
- Contains an organic and soluble compound that affects the setting time and properties of cement.
- The presence of impurities such as clay, dust and silt coatings, increase water requirement and impair bond between cement paste and aggregate.

To this effect, this research is carried out to study the suitability of crushed sand full replacement of natural sand.

1.3 Objectives

1.3.1 General objective

The general objective of this research work is to study the impact of crushed sand for concrete on the bulking of sand and compare the result of workability, compressive strength and water absorption in concrete produced using natural sand.

1.3.2 Specific objective

The specific objectives of this research are:

- Bulking of sand is compared the property exists for natural sand, this should be established by the experiment on both types of sands and by developing a result related graph for these two sands.
- To determine the strength of concrete (C-20mpa, C-25mpa and C-30mpa)
- To study the effect of workability on the properties of concrete with crushed sand.
- To determine the rate of water absorption of concrete.
- Compare the economic cost of the crushed and natural sand.

1.4 Significance of the study

This research will have significance for the production of concrete by:

- Assisting the current fast growing construction industry by providing an alternative to the widely used natural sand.
- To assess existing concrete produced quality using crushed sand.
- Attaining a comparative cost advantage crushed sand is cheaper than that of natural sand.

1.5 Methodology

The following methodology have been employed to achieve the objectives of this research

Stage 1: Literature review

A comprehensive literature review was made to understand the previous efforts and the laboratory testing procedures, which include the review of textbooks, publications and academic journals, seminar, conference and research papers.

Stage 2: Experimental study

1. Experimental studies on crushed sand and natural sand for concrete: - Conducting bulking of sand, workability, compressive strength and water absorption analysis was conducted.
2. Different mixes targeting at workability of concrete, compressive strength and water absorption of C-20 MPa, C-25 MPa and C-30 MPa.
    - ❖ Each grade of concrete was prepared with nine different mix proportions and for each sand material nine mix for water absorption test.
    - ❖ The other constituent material was constant.
    - ❖ For compressive strength test twenty-seven cubes concrete sample were casted on both sand for 7th, 14^{th} and 28th days.
    - ❖ For water absorption test of was casted twelve concrete sample for 7th and 28th days from each sand.
3. Based on the results, conclusions and recommendations are given.

CHAPTER - II

2. Literature Review

2.1. Properties of concrete

2.1.1 Properties of Fresh Concrete

Fresh concrete is defined as concrete at the state when its components are fully mixed but its strength has not yet developed. This period corresponds to the cement hydration stages 1, 2, and 3. The properties of fresh concrete directly influence the handling, placing and consolidation, as well as the properties of hardened concrete. Some of important properties of fresh concrete are discussed as follows: -

2.1.1.1 Workability

Workability is a general term to describe the properties of fresh concrete. Workability is often defined as the amount of mechanical work required for full compaction of the concrete without segregation. This is a useful definition because the final strength of the concrete is largely influenced by the degree of compaction. A small increase in void content due to insufficient compaction could lead to a large decease in strength.

The primary characteristics of workability are consistency (or fluidity) and cohesiveness. Consistency is used to measure the ease of flow of fresh concrete.

2.1.1.2 Setting

Setting is defined as the onset of rigidity in fresh concrete. It can also be defined as the transition process of changing of concrete from plastic state to hardened state. It is different from hardening, which describes the development of useful and measurable strength. Setting precedes hardening although both are controlled by the continuing hydration of the cement.

2.1.1.3 Segregation

The separation of concrete ingredients from each other is known as segregation. This can be caused due to excessive vibration in concrete mixer machine or falling concrete from more than 1-meter height.

2.1.2 Properties of Hardened Concrete

The major properties of hardened concrete are: strength, modulus of elasticity, durability, creep and shrinkage. Some of them will be discussed as follows: -

2.1.2.1 Strength of concrete

Strength of concrete is commonly considered its most valuable property, although in many practical cases other characteristics such as durability and impermeability may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste.

Of all, compressive strength of concrete is the most important one because the best quality of concrete is in its compression resistance or capacity. More over other strengths like flexural and tensile can be correlated to this property. The 3, 7 and 28-day compressive strength of concrete will be determined by a standard uniaxial compression test is accepted universally as a general index of concrete strength.

2.1.2.2 Durability

The durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposure environment and the properties desired. The concrete ingredients, proportioning of those ingredients, interactions between the ingredients, and placing and curing practices determine the ultimate durability and life of the concrete.

2.2 Aggregate
2.2.1 General

Aggregates are defined as inert, granular, and inorganic materials that normally consist of stone or stone-like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete. The most popular use of aggregates is to form Portland cement concrete. Approximately three-fourths of the volume of Portland cement concrete is occupied by aggregate. It is inevitable that a constituent occupying such a large percentage of the mass should have an important effect on the properties of both the fresh and hardened products. [5]

2.2.2 Classification of aggregate

Aggregates can be divided into several categories according to different criteria. [6]

A. In accordance with size:
   - Coarse aggregate: Aggregates predominately retained on the 4.75 mm sieve. [7]
   - Fine aggregate (sand): Aggregates passing No.4 (4.75 mm) sieve and predominately retained on the 75 µm sieve. [7]

B. In accordance with unit weight
   - Lightweight aggregate: The unit weight of aggregate is less than 1120 kg/m3. The corresponding concrete has a bulk density less than 1800 kg/m3.
   - Normal weight aggregate: The aggregate has unit weight of 1520-1680 kg/m3. The concrete made with this type of aggregate has a bulk density of 2300-2400 kg/m3.
   - Heavy weight aggregate: The unit weight is greater than 2100 kg/m3. The bulk density of the corresponding concrete is greater than 3200 kg/m3.

C. In accordance with sources:
   - Natural aggregates: This kind of aggregate is taken from natural deposits without changing their nature during the process of production such as crushing and grinding.
   - Manufactured aggregates: This is a kind of man-made materials produced as a main product or an industrial by-product.

2.2.3 Physical Properties of Aggregates

Since at least three-quarters of the volume of concrete is occupied by aggregate, the physical properties of the aggregate greatly affect the strength, durability and structural performance of concrete. Therefore, the physical properties of aggregates should be well tested and known to produce the right quality of concrete. Important properties of aggregate that affect the performance of concrete are discussed as follows: - [8]

A. Sampling

Samples shall be representative and certain precautions in sampling have to be made. No detailed procedures can be laid down as the conditions and situations involved in taking samples in the field can vary widely from case to case. Nevertheless, a practitioner can obtain reliable results bearing in mind that the sample taken is to be representative of the bulk of the material.

The main sample shall be made up of portions drawn from different parts of the whole. The minimum number of these portions is described in BS 812; part 105; 1990 [6].

The main sample may be rather large, and so the sample has to be reduced before testing. To maintain the representative sample, quartering or riffling reduction techniques are used. [6]

B. Particle shape and surface texture

Roundness measures the relative sharpness or angularity of the edges and corners of a particle. Roundness is controlled largely by the strength and abrasion resistance of the parent rock and by the amount of wear to which the particle has been subjected. In the case of crushed aggregate, the particle shape depends not only on the nature of the parent rock but also on the type of crusher and its reduction ratio, i.e. the ratio of the size of material fed into the crusher to the size of the finished product. Particles with a high ratio of surface area to volume are also of particular interest for a given workability of the control mix. The flakiness and elongation tests are useful for general assessment of aggregate but they do not adequately describe the particle shape. The presence of elongated particles in excess of 10 to 15% of the mass of coarse aggregate is generally undesirable, but no recognized limits are laid down . [6]

Surface texture of the aggregate affects its bond to the cement paste and also influences the water demand of the mix, especially in the case of fine aggregate. The shape and surface texture of aggregate influence considerably the strength of concrete. The effects of shape and texture are particularly significant in the case of high strength concrete. The full role of shape and texture of aggregate in the development of concrete strength is not known, but possibly a rougher texture results in a larger adhesive force between the particles and the cement matrix. The shape and texture of fine aggregate have a significant effect on the water requirement of a mix made with the given aggregate. Flakiness and shape of coarse aggregates have an appreciable effect on the workability of concrete . [6]

C. Grading of fine and coarse aggregate

The grading determines the paste requirement for a workable concrete since the amount of void requires needs to be filled by the same amount of cement paste in a concrete mixture. To obtain a grading curve for aggregate, sieve analysis will be conduct. [7]

D. Bond of aggregate

Bond between aggregate and cement paste is an important factor in the strength of concrete, but the nature of bond is not fully understood. A rougher surface, such as that of crushed particles, results in a better bond due to mechanical interlocking. In addition, bond is affected by other physical and chemical properties of aggregate, related to its mineralogical and chemical composition, and to the electrostatic condition of the particle surface. In any case, for good development of bond, it is necessary that the aggregate surface be clean and free from adhering clay particles . [6]

The determination of the quality of bond of aggregate is difficult and no accepted tests exist. Generally, when bond is good, a crushed specimen of normal strength concrete should contain some aggregate particles broken right through, in addition to the more numerous ones pulled out from their sockets. An excess of fractured particles, might suggest that the aggregate is too weak . [6]

E. Strength of aggregate

The compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained. If the aggregate under test leads to a lower compressive strength of concrete, and in particular if numerous individual aggregate particles appear fractured after the concrete specimen has been crushed, then the strength of the aggregate is lower than the nominal compressive strength of the concrete mix. Such aggregate can be used only in a concrete of lower strength. Thus a low strength may be due to the weakness of constituent grains or the grains may be strong but not cemented together . [6]

F. Deleterious Substance of aggregate

For satisfactory performance, concrete aggregates should be free of deleterious materials. There are three categories of deleterious substances that may be found in aggregates: impurities, coatings and weak or unsound particles. [8]

2.2.4 Coarse Aggregate

The maximum size of coarse aggregate is typically 19 mm or 25 mm. An intermediate-sized aggregate, around 9.5 mm, is sometimes added to improve the overall aggregate gradation. [7] The most commonly available local coarse aggregates are obtained from normal weight crushed basaltic rocks and lightweight volcanic ash, which are a member of a family of igneous rock (scoria or pumice). [7]

2.2.5 **Fine Aggregate**

Aggregate passing through 4.75 mm sieve are defined as fine. They may be natural sand deposited by rivers and crushed sand obtained by crushing stones. [6]

2.2.5.1 **Types of Fine Aggregate**

2.2.5.1.1 **Crushed Sand**

Crushed sand is used for aggregate materials having dimensions less than 5.0mm that are processed from crushed rock or gravel and intended for construction use. The use of crushed sand in concrete has been known since the Roman time. In modern technology, natural aggregates have proved to be significantly economical in use, for which reason extensive use of crushed sand has been concentrated to regions or projects where the availability of natural aggregates has been limited. [8]

The growing problem of surplus fines from hard rock quarries has, however, in recent times encouraged a development towards more use of manufactured aggregates in many populated areas, and for several concrete applications. [9]

Crushed sand has rough surface texture and the particle size distribution curve can be adjusted in the manufacturing of the material. Crushed sands are made by crushing aggregate to size appropriate for use as a fine aggregate (< 5.0mm). The crushing process caused the manufactured sand to have an irregular particle shape. These fine particles and irregular shape of the aggregate have detrimental effects on the workability and finish of the concrete. These negative effects have given manufactured sands a poor reputation in the construction industry.

2.2.5.1.2 **Natural River Sand**

Rivers sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. An individual particle in this range size is termed a sand grain. Sand grains are between gravel and silt. [6]

The construction industry in Ethiopia mainly uses sand from streambeds, which are commonly derived from quartz-feldspathic basement rock, sandy marine sediments and alluvial deposits. The major sand supply for the construction works in and around Addis Ababa is the Awash basin located about 70-198 km southeast of the city . [8]

2.2.6 Requirement of Sand for concrete

Aggregate provides technical advantage on concrete which has higher volume stability better than the cement paste alone. So, before using aggregate as concrete making material, it is important to examine whether those aggregates fit for the purpose to which they are intended to be used and tests on site and laboratory should have to be made. Some of the requirement will be discussed below:

2.2.6.1 Grading of sand:

Fine aggregate grading has a greater effect on workability of concrete than coarse aggregates. The grading determines the paste requirement for a workable concrete since the amount of void requires needs to be filled by the same amount of cement paste in a concrete mixture.

To obtain a grading curve for aggregate, sieve analysis will be conduct. According to ES C.D3.201, BS882 and ASTM the grading requirement of fine aggregate, are summarized as shown in Table 1. [7]

Table 1:BS and ASTM grading requirement for fine aggregate

Sieve size		Percentage by weight passing sieves				
		BS 882:1973 [8]				ASTM standard C33-78
BS	ASTM No.	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4	
9.5mm	3/4in	100	100	100	100	100
4.75mm	3/16in	90-100	90-100	95-100	95-100	90-100
2.36mm	8	60-95	75-100	85-100	95-100	80-100
1.18mm	16	30-70	55-90	75-100	90-100	50-85
600μm	30	15-34	35-59	60-79	80-100	25-60
300 μm	50	5-20	8-30	12-40	15-50	10-30
150 μm	100	0-10	0-10	0-10	0-15	2-10

2.2.6.2 Fineness Modulus

Using the sieve analysis results, a numerical index called the fineness modulus (FM) is often computed. The FM is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100.

The specified sieves are 9.5 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600µm, 300 µm, and 150 µm (No. 4, 8, 16, 30, 50, and 100). Note that the lower limit of the specified series of sieves is the 150 µm (No. 100) sieve and that the actual size of the openings in each larger sieve is twice that of the sieve below. The coarser the aggregate size, the higher the FM. For fine aggregate used in concrete, the FM generally ranges from 2.3 to 3.1 as called for in ASTM C 33. [5]

It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of grading which will produce a given fineness modulus. The following limits may be taken as guidance. [5]

- Fine sand: F.M. 2.2 - 2.6
- Medium Sand: F.M. 2.6 - 2.9
- Coarse Sand: F.M. 2.9 - 3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete [11]. However, it is clear that one parameter, the average, cannot be representative of a distribution: thus the same fineness modulus can represent an infinite number of totally different size distributions or grading curves.

The fineness modulus cannot, therefore, be used as a description of a grading of an aggregate but it is valuable for measuring slight variations in the aggregate from the same source. [6]

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete. However, it is clear that one parameter, the average, cannot be representative of a distribution: thus the same fineness modulus can represent an infinite number of totally different size distributions or grading curves. [7]

The fineness modulus cannot, therefore, be used as a description of a grading of an aggregate but it is valuable for measuring slight variations in the aggregate from the same source. [6]

2.2.6.3 Silt Content

Sand is a product of natural or artificial disintegration of rocks and minerals. Sand is obtained from glacial, river, lake, marine, residual and wind-blown (very fine sand) deposits. These deposits, however, do not provide pure sand. They often contain other materials such as dust, loam and clay that are finer than sand. Therefore, it is necessary that one make a test on the silt content and checks against permissible limits.

A simple test which can be made on site to give a guide to the amount of silt in natural sand is the 'field settling' test. This test should not be used for crushed rock sands.

According to the Ethiopian Standard it is recommended to wash the sand or reject if the silt content exceeds a value of 6%. [5]

2.2.7 **Properties of Good Sand** [1]

- It should be clean and coarse.
- It should be free from any organic or vegetable matter; usually 3-4 percent clay is permitted. It should be chemically inert.
- It should contain sharp, angular, coarse and durable grains.
- It should not contain salts, which attract moisture from the atmosphere.
- It should be well graded, i.e., it should contain particles of various sizes in suitable proportions. It should be strong and durable.
- It should be clean and free from coatings of clay and silt.

2.3 Crushed sand for Concrete

2.3.1 General

Crushed sand is a substitute of river sand for concrete construction. Crushed sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of Crushed sand is less than 4.75mm. [7]

2.3.2 Use of Crushed sand

Crushed sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the world. Due to the depletion of good quality river sand for the use of construction, the use of Crushed sand has been increased. Another reason for the use of M-Sand is its availability and transportation cost. Since Crushed sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed. Thus, the cost of construction can be controlled by the use of Crushed sand as an alternative material for construction. The other advantage of using Crushed sand is, it can be dust free, the sizes of Crushed sand can be controlled easily so that it meets the required grade for the given construction. [6]

” it is well graded in the required proportion.

” It does not contain organic and soluble compound that affects the setting time and properties of cement, thus the required strength of concrete can be maintained.

” It does not have the presence of impurities such as clay, dust and silt coatings, increase water requirement as in the case of river sand which impair bond between cement paste and aggregate. Thus, increased quality and durability of concrete.

” Crushed sand is obtained from specific hard rock (granite) using the state-of-the-art International technology, thus the required property of sand is obtained.

” Crushed sand is cubical in shape and is manufactured using technology like High Carbon steel hit rock and then ROCK ON ROCK process which is synonymous to that of natural process undergoing in river sand information.

” Modern and imported machines are used to produce Crushed sand to ensure required grading zone for the sand.

2.4 Comparison of Crushed Sand and Natural Sand

Natural sand / River sand has been used in construction for many centuries. Recently for past few years due to various reasons, we have to use crushed sand. Properties and applications of crushed sand comparing with natural sand. [8]

Natural sand has an ideal shape for use as fine aggregate in concrete. The natural sand particles are well-rounded and are usually nearly spherical. Spherical particles decrease the percentage of voids within the concrete mixture so no additional paste is required to fill these voids. Well-shaped natural sands are ideal for workability of mixtures. Natural sand does not require more water to enhance the workability of the mixture so the amount of bleed water in the concrete will not be increased. [9]

Crushed sand is produced by reducing larger pieces of aggregate into sand-sized aggregate particles. Crushed sand tend to be used in mixtures in areas where natural sand is not available or not cost effective to be hauled to the needed location. Crushed sand tends to be more angular and flaky due to the crushing process. Highly angular particles tend to increase the paste content of concrete because additional lubrication is required for particles with sharp corners. [9]

2.5 The impact of using crushed sand on concrete properties

Increase in strength characteristics of concrete has been observed as compared to concrete made with natural river sand is mainly due to denser particle packing and silt free nature as compared to river sand. International center for aggregate research (ICAR) has conducted extensive research on the use of manufactured micro fines, up to 17%, in consort with promising results. ICAR 102 studied the uses of micro fines in Portland cement concrete and determined the effects of higher amount of crusher fines on fresh and hardened concrete properties. The amount of fines passing the No. 200 sieve (75 μm) ranged from 7.4 to 16.7%. [9]

Researchers concluded that, compared to concrete made from natural sand, high fines concrete generally had higher flexural strength, improved abrasion resistance, and higher unit weight and lower permeability due to filling the pores with micro fines. There is no appreciable difference in dry shrinkage in concrete made with manufactured sand as compared to river sand.

Crushed sand is more angular and has a rougher surface texture than naturally weathered sand particles. Aggregate that is more angular will have more water demands compared to river sand. Increase in water demand has to be compensated by the increasing cement content to maintain the same water cement ratio. Their particle size distribution helps in higher packing density, which enhances the durability of the concrete. Mr. Vijay K. Kosaraju. Executive Director of Robo Silicon limited concluded that Crushed sand is anytime better than river sand.

The particle shape is cubical, which is almost closer to rounded river sand. The gradation what we get generally won't be available in any river sand. It is also a proven fact, that the compressive strength of any grade of concrete is much more than the concrete where river sand is used. [9]

2.6 Some Studies on Crushed sand for concrete

Common river sand is expensive due to the excessive cost of transportation from natural sources. In addition, large-scale depletion of these sources creates environmental problems. As environmental, transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas.

Studies on the replacement of natural sand by artificial sand. They concluded from experimental results that, mixes with an artificial sand as a fine aggregate gives better strengths than mixes of natural sand due to sharp ages of the particle in artificial and provide a better bond with cement than a rounded particle of natural sand. [10]

Investigate the effect of Crushed sand in structural concrete by replacing river sand and develop a high-performance concrete. It is proposed to determine and compare the differences in properties of concrete containing river sand and Crushed sand. It is also proposed to use steel fibers and chemical admixtures to increase the strength and workability of concrete respectively. The investigations are to be carried out using several tests which include workability test, compressive test, tensile test, and flexural test. [11]

Studies the influence that Crushed sand have in compressive strength of concrete, and to access the prospects of using Crushed sand as replacement of natural sand. The results of the hardened properties of the mixes have shown that concrete mixes with partial proportions of Crushed sand and natural sand achieved a higher compressive strength at all test ages.

It can, therefore, be concluded from the finding of this study that when the availability of natural sand is scarce or in cities where the price of natural sand is as expensive as manufactured one, Crushed sand concrete mix is a viable and better alternative to the use of natural sand. [12]

Presented reviewed of research work on effects of artificial sand on compressive strength and workability of concrete. A brief summary of the most significant investigations on the behavior of concrete by replacing natural sand with artificial sand due to which environmental and social problems arise due to acute shortage of natural sand will be overcome. [13]

Investigated the performance of this concrete in term of its compressive strength and split tensile strength. This paper puts forward the applications of Crushed sand as an attempt towards sustainable development in India. It will help to find a viable solution of the declining availability of natural sand to make eco-balance. Crushed sand is one among such materials to replace river sand, which can be used as an alternative fine aggregate in mortars and concretes. The use of Crushed sand in concrete is gaining momentum these days. The present experimental investigations have been made of concrete using Crushed sand as fine aggregate and observed the effects of crushed sand on strength properties of concrete. [14]

CHAPTER – III

3. Experimental program

3.1 General

The experimental program was divided into four parts. The first part was determining the amount of surface moisture in fine aggregate by bulking of sand test. The second and third part of the program focused on the optimization of the selected concrete grade compressive strength and workability. The fourth part was determining the amount of water in concrete spaceman by water absorption test.

3.2 Material used

The materials usually used in the concrete mix are cement, fine aggregate (crushed sand &natural sand), coarse aggregate and water.

3.2.1 Cement

The cement used in this experimental study is Ordinary Portland Cement (OPC grade cement).

Figure 1: Cement

3.2.2 Fine Aggregate

Two kinds of fine aggregate were used in this research. One was natural sand from Meki around Zeway, the other was Crushed sand made in Akike crushed stone suppliers.

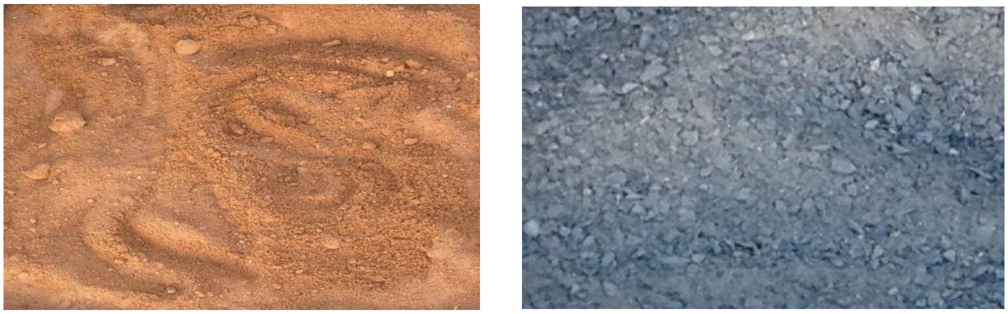


Figure 2: Natural Sand and Crushed Sand

Table 2 Properties of Fine aggregate

Property	Natural sand	Crushed sand
Specific gravity	2.59	2.81
Bulking Specific gravity	2.51	2.79
Water absorption (%)	3.31	3.31
Fineness modulus	2.57	2.99

3.2.3 Coarse aggregate

Coarse aggregate of nominal size of 20mm is preferred and tests to determine the different physical properties as per ACI code.

Figure 3 Coarse Aggregate

3.2.4 Water

Water is one of the most important elements in concrete production. Water is needed to begin the hydration process by reacting with the cement to produce concrete. There has to be a sufficient amount of water available so that the reaction can take its full course, but if too much water is added, this will in fact decrease the strength of the concrete. The water-cement ratio is an important concept because other than the recipe for the concrete mix, the amount of water used would also determine its final strength.

3.3 Mix Proportions and Mix Details

3.3.1 Mix proportion

Concrete mix design in this investigation was designed as per the guidelines specified. Show in tables below the concrete mix proportions. The mix proportions were arrived at by preparing a number of trial mix and testing each mix for it workability, strength and its water absorption of concrete.

Using the final mix proportion of the design of C-20, C-25 and C-30, 54 cubes (150x150x150mm size) for both sand cast and well cured. 18 cubes were tested to find 7th, 14th and 28th day compressive strength and the other once use for the water absorption test. Casting and testing of cubes were done strictly according to the procedures laid down in ACI 211.1 standard specifications.

Table 3 Details of final mix proportion(attached in the appendix)

Martial	Mix design C-20				
	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (L/m^3)	**w/c**
Natural sand	332.0	771	1172.2	166.9	0.5
Crushed sand	348.1	739.1	1172.2	182.0	0.52

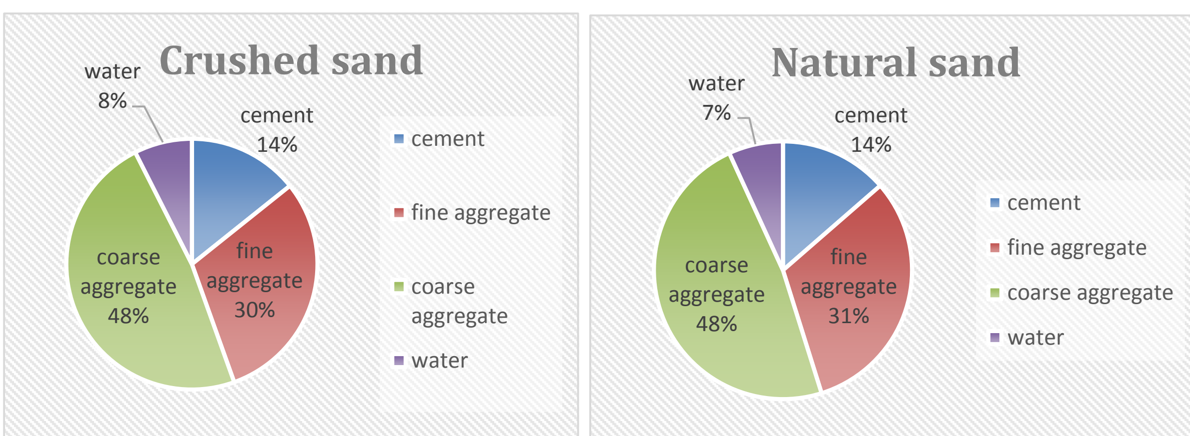


Figure 4 Natural Sand mix proportion and Crushed Sand mix proportion

Table 4:Details of final mix proportion

Martial	Mix design C-25				
	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (L/m^3)	**w/c**
Natural sand	358	730.9	1172.2	180	0.50
Crushed sand	371.2	702.9	1172.2	194	0.52

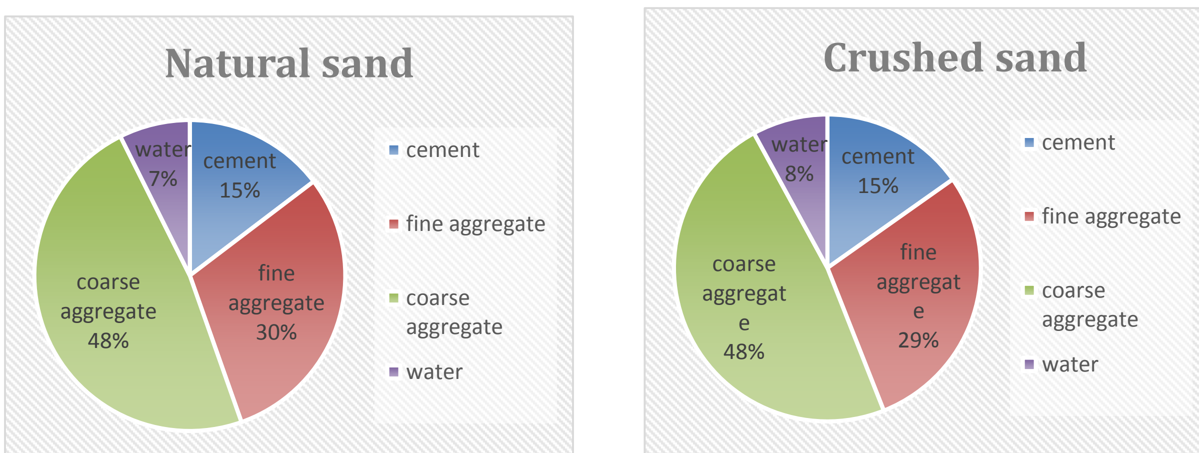


Figure 5 Natural Sand mix proportion and Crushed Sand mix proportion

Table 5 Details of final mix proportion

Martial	Mix design C-30				
	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (L/m^3)	**w/c**
Natural sand	360.0	727.8	1172.2	181.0	0.5
Crushed sand	371.2	702.9	1172.2	194	0.52

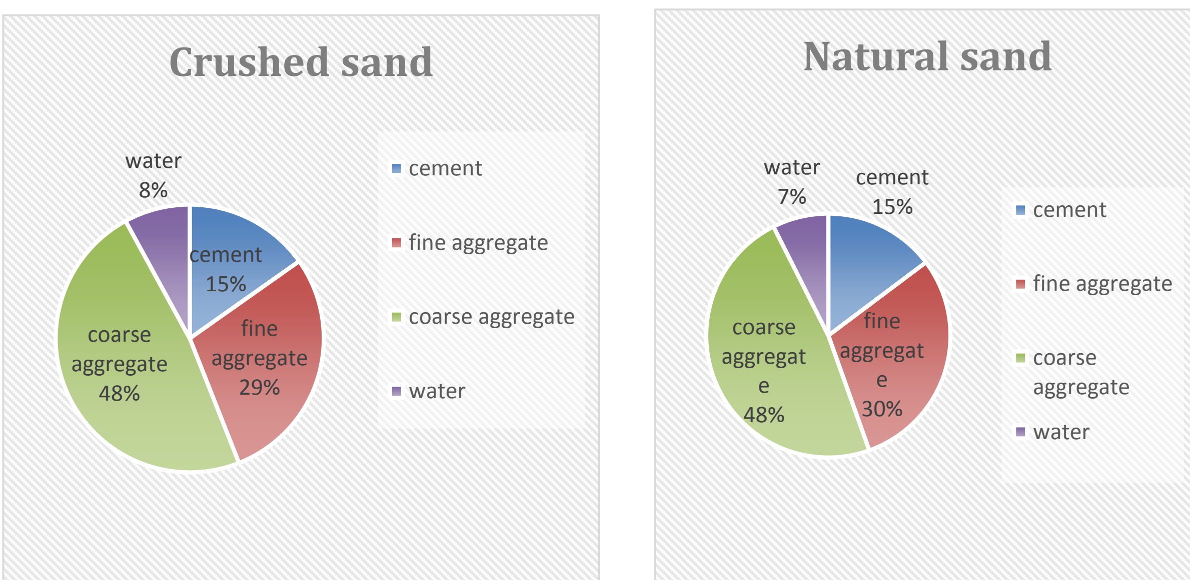


Figure 6 Natural Sand mix proportion and Crushed Sand mix proportion

CHAPTER - IV

4. Results and Discussion

4.1 GENERAL

The present experimental study of this thesis research to substitute natural sand by crushed sand and the result of two sand material with bulking of sand, workability, compressive strength and water absorption of concrete for C-20, C-25 C-30 grade concrete Below are the results obtained and the details of the discussions. The analysis of the results is shown and contained in the tables, graph and chart below.

4.2 Bulking of sand test

Bulking in sand Occurs When dry, sand interacts with the atmospheric moisture. Presence of moisture content forms a thin layer around sand particles. This layer generates the force, which makes the particles to move aside each other. This results in the increase of the volume of sand. Excessive presence of moisture content in the sand makes concrete with less durable and loses its strength. Remember, excessive presence of moisture content increases the workability of concrete, but loses its strength. As per ACI, Presence of 4% of moisture content in sand increases 25% of its volume. [6]

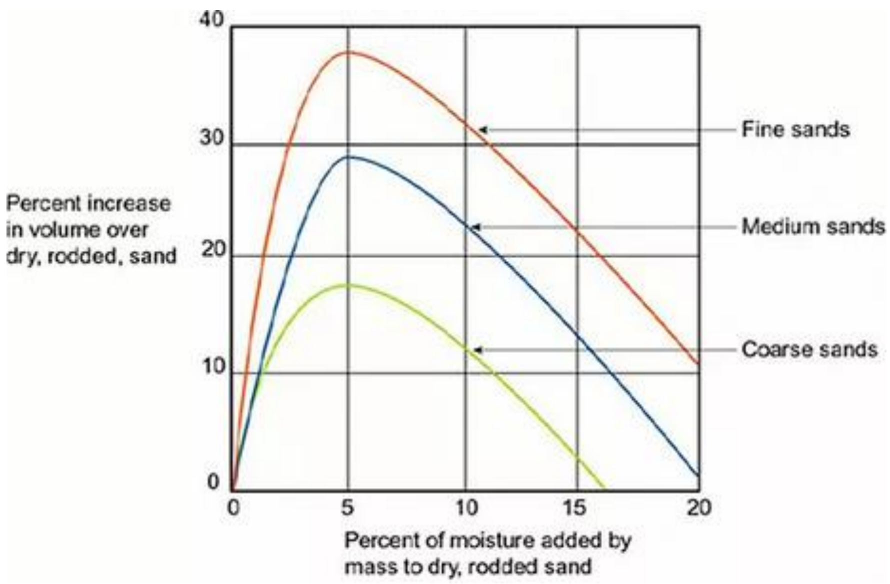


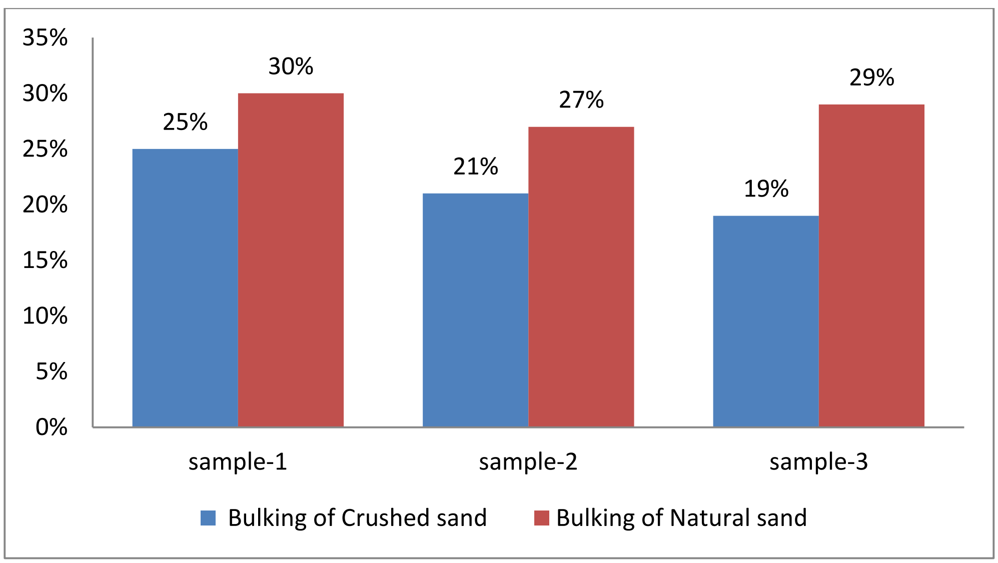
Chart 1:Surface moisture on fine aggregate can cause considerable bulking; the amount varies with the amount of moisture and the aggregate grading (PCA Major Series 172 and PCA ST20).

The extent of sand bulking depends on the grading of sand. Finer Sand possesses more bulking than the medium and coarse sand. Thus, bulking in the sand is high for fine sand and low for coarse sand. An increase of bulking in sound effects concrete mix and results harsh behavior while placing. Moisture content less than 5% should be preferred for construction purposes.

The bulking of sand is the property of change of volume when water is added to the material. Bulking is a major problem while mixing the concrete. A measuring jar is taken and sad is filled up-to a mark in the measuring jar. Then water is added up to the highest mark in the vessel and left it for settling and the settled height is measured and the percentage bulking is calculated. (see in Fig.7)

Table 6:Percentage of Bulking of sand

No. Sample	Percent of Bulking of Crushed sand	Percent of Bulking of Natural sand
sample-1	25%	30%
sample-2	21%	27%
Sample-3	19%	29%



GRAPH 1 Comparison of Bulking of san

Figure 7 Bulking of sand test

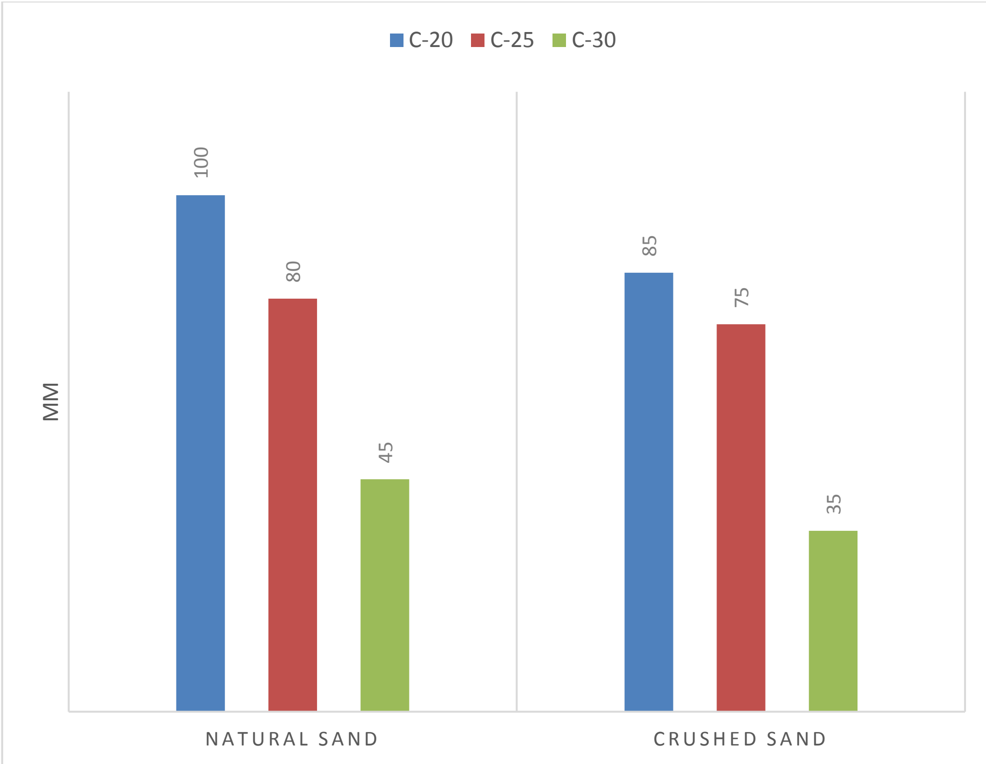
4.3 Workability or Slump

Generally concrete slump value is used to find the workability, which indicates water-cement ratio, but there are various factors, including properties of materials, mixing methods, amount, admixtures etc. also affect the concrete slump value. If the water added is more which will lead to bleeding or segregation of aggregates. In our case we have used slump cone test for measuring the workability of concrete. We have ensured the height of the fall of the cone of concrete for various water-cement ratios and recorded the values for ordinary concrete. Then the same procedure is done with the concrete having the full replacement of natural sand with crushed sand. (Fig 8)

Each proportion of the experimental concrete mix was tested for workability by the slump test as per ACI standard. The workability of concrete was measured in terms of the slump value. The values of slump measured in mm and the results indicate of all grades of concrete is better with natural sand and crushed sand but with crushed sand workability is poor, mix looks harsh. The results of workability are shown in below.

Table 7:Results of Slump Test on Concrete

Mix proportion	Expected Slump mm	Observed Slump value (mm)	
Grade(Mpa)		Natural sand	Crushed sand
C-20	25-100	100	85
C-25		80	75
C-30		45	35



GRAPH 2 Comparison of Slump Value

Figure 8 Slump cone test in laboratory

4.4 Compressive Strength

The compressive strength of the concrete was determined in accordance with ACI code 211.1 Standards, to find compressive strength C-20, C-25 and C-30 cubes of size 150 x 150 x150 mm for each of nine mixes were cast and caring. The cube specimens were tested under compression. The average compressive strength results are reported as the age of 7^{th}, 14^{th} and 28^{th} days in Table 6 and 7. Crushed sand compared to natural sand and an increase of more than 6 % compared to that with natural sand. Reason for higher strength with crushed sand with compared to natural sand. Show in below

Table 8 Compressive Strength Test Results for natural sand

no. samples	C-20 mpa		
	7 day	14 day	28 day
sample-1	17.65	20.48	23.3
sample-2	18.25	20.97	23.69
Sample-3	17.95	21.10	24.25
average	**17.95**	**20.85**	**23.7**
Target Average Compressive Strength			**25**

Table 9 Compressive Strength Test Results for crushed sand

no. samples	C-20 mpa		
	7 day	14 day	28 day
sample-1	19.7	21.55	23.4
sample-2	18.6	21.74	24.87
Sample-3	18.03	21.56	25.08
average	**18.78**	**21.61**	**24.45**
Target Average Compressive Strength			**25**

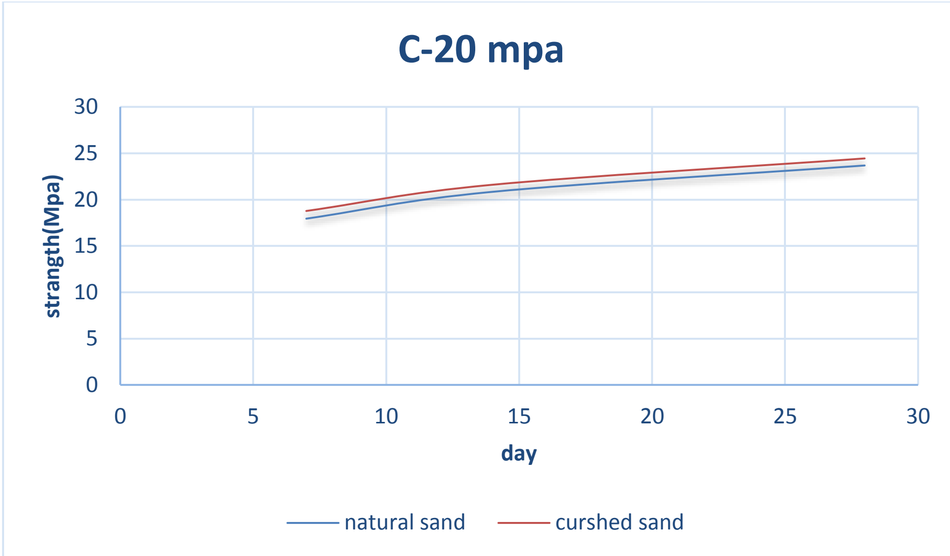


Chart 2Comparison of compressive strength of Natural and Crushed sand

Table 10 Compressive Strength Test Results for natural sand

no. samples	C-25 mpa		
	7 day	14 day	28 day
sample-1	18.89	24.38	26.87
sample-2	17.69	23.42	27.16
Sample-3	18.44	24.82	28.2
average	**18.34**	**24.21**	**27.41**
Target Average Compressive Strength			**28**

Table 11 Compressive Strength Test Results for crushed sand

no. samples	C-25 mpa		
	7 day	14 day	28 day
sample-1	20	24.98	29.96
sample-2	20.89	24	27.11
Sample-3	20.8	24.055	27.31
average	**20.56**	**24.34**	**28.13**
Target Average Compressive Strength			**28**

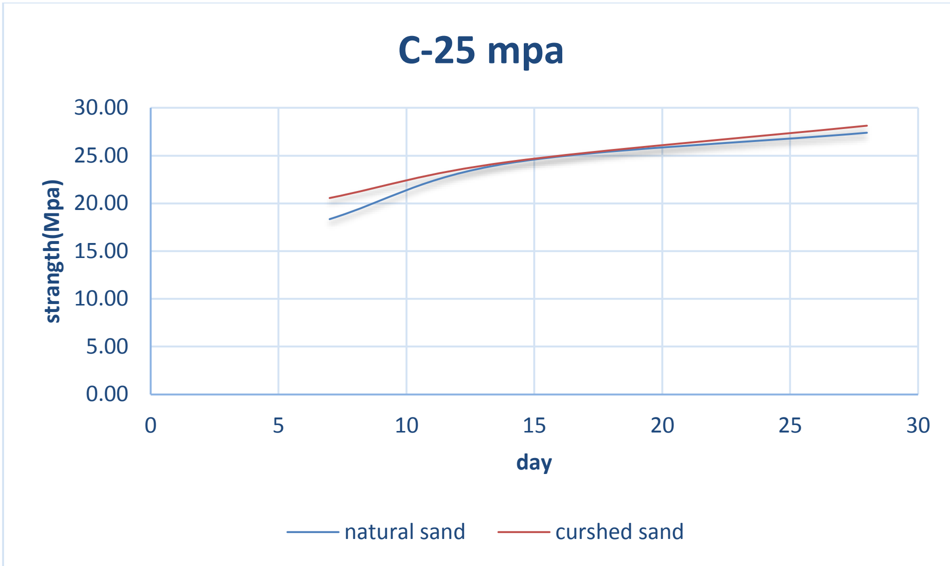


Chart 3:Comparison of compressive strength of Natural and Crushed sand

Table 12 Compressive Strength Test Results for natural sand

no. samples	C-30 mpa		
	7 day	14 day	28 day
sample-1	22.37	26.24	30.1
sample-2	22.86	25.62	28.37
Sample-3	23.95	25.94	27.93
average	**23.06**	**25.93**	**28.80**
Target Average Compressive Strength			**30**

Table 13 Compressive Strength Test Results for crushed sand

no. samples	C-30 mpa		
	7 day	14 day	28 day
sample-1	27.56	27.92	28.27
sample-2	23.25	28.30	33.34
Sample-3	27.91	30.08	32.25
average	**26.24**	**28.76**	**31.29**
Target Average Compressive Strength			**30**

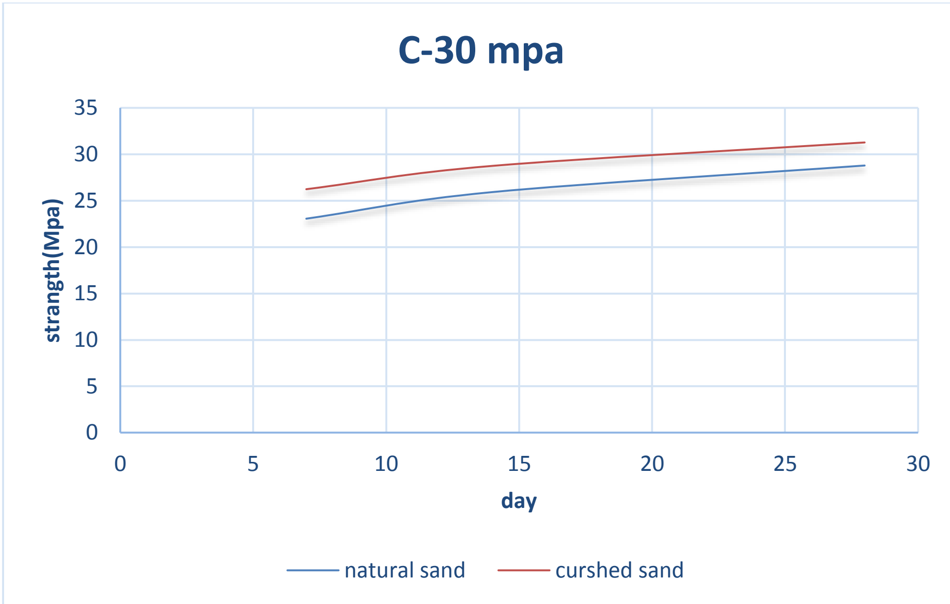


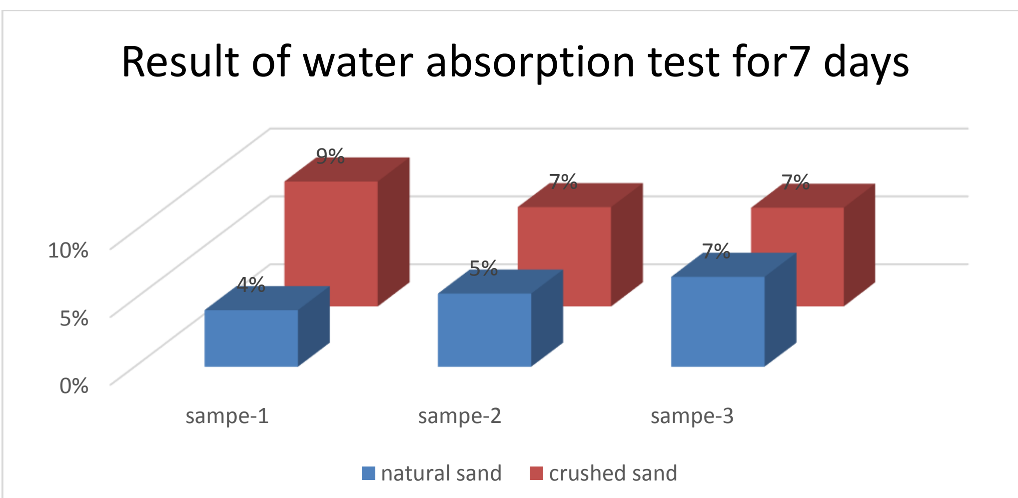
Chart 4 Comparison of compressive strength of Natural and Crushed sand

4.5 Water absorption

The C-25 cubes of size 150 x 150 x150 mm after casting were immersed in water for 7^{th} and 28^{th} days curing. These specimens were then oven dried for 24 hours at the temperature$110^{\pm 5}$°C until the mass became constant and again weighed. This weight was noted as the dry weight of the cubes. After completion of testing, comparing water absorption of concrete with different sand materials use for 7 day of crushed sand the percentages of concrete specimens are greater than on 3% of natural sand, and the percentage of water absorption after 28 days is greater than on 2% crushed sand with natural sand. Therefore, water absorption of C-25 concrete use natural sand is lower water absorption.

Table 14 Result of water absorption test for 7 days

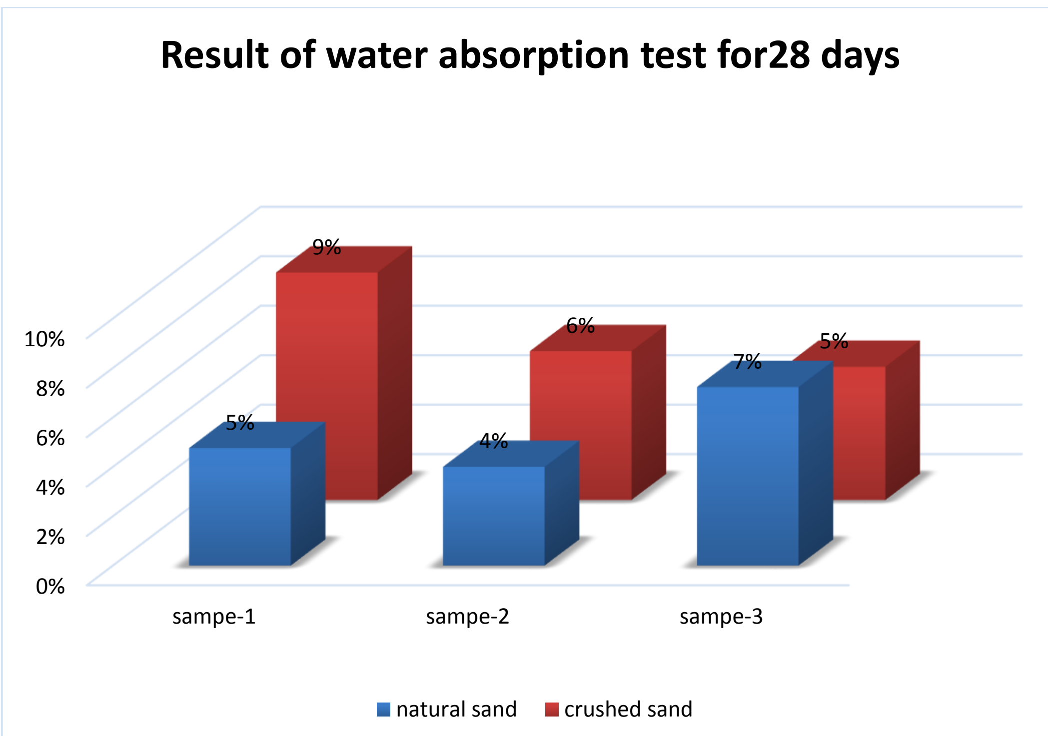
Material	7day		
	sample	% water absorption	Average % water absorption
Natural Sand	sampe-1	4%	5%
	sampe-2	5%	
	sampe-3	7%	
Crushed Sand	sampe-1	9%	8%
	sampe-2	7%	
	sampe-3	7%	



GRAPH 3 Comparison of water absorption test for 7 days

Table 15 Result of water absorption test for 28 days

Material	28 day		
	sample	% water absorption	Average % water absorption
Natural Sand(NS)	sampe-1	5%	5%
	sampe-2	4%	
	sampe-3	7%	
Crushed Sand(CS)	sampe-1	9%	7%
	sampe-2	6%	
	sampe-3	5%	



GRAPH 4 Comparison of water absorption test for 28 days

CHAPTER - V

5. Cost Analysis

5.1 General

It can be formulated that aggregate production in Ethiopia has been and will continue to be a local business based on easily accessible natural deposits. Most of the aggregate quarries in around Addis Ababa are owned by the farmers and government. they sell their product or lease the quarry to contractors for different works. These types of quarry are scattered around the country, mainly close to major roads while some are far away from roads. Though aggregates from natural sand and gravel deposits don’t contain fine particles in proportion and also have more impurities, the experience of crushed sand is limited to specific projects. In addition, as can be seen from the experience of crushed sand in Ethiopia, the material properties differ in many ways from those found in natural sand, even though the particles sizes are similar.

The true cost of aggregate material is influenced by various factors, since production and transportation costs play the major role.

5.2 Cost-Concrete Mix

In concrete production for $1m^3$ cost breakdown compared with natural sand and crushed sand in current martial price.

➔ Natural sand

Table 16 For $1m^3$ use natural sand concrete price

Material	value	unit	[redacted]		
Water	180.0	Lit/m3		13.8	Birr/m^3
Cement	358.0	Kg/m3	8 bag	355*4=1420	Birr/qt
Sand	730.9	Kg/m3	27 box	550	Birr/m^3
Coarse Aggregate	1172.2	Kg/m3	43 box	565	Birr/m^3
			Total	**2548.8**	Birr/m^3

➔ Crushed sand

Table 17 For $1m^3$ use crushed sand concrete price

Material	value	unit	[redacted]	[redacted]	[redacted]
Water	194.0	Lit/m3		13.8	Birr/m^3
Cement	371.2	Kg/m3	8 bag	355*4=1420	Birr/qt
Sand	702.9	Kg/m3	26 box	420	Birr/m^3
Coarse Aggregate	1172.2	Kg/m3	43 box	565	Birr/m^3
			Total	**2418.8**	Birr/m^3

5.3 Cost-Distance relationship

The cost of natural sand material is influenced by various factor, hence production and transportation costs play the major role. Based on the information average production cost, transport cost others cost sees in the table-12. Crushed sand is from 400 birr – 420 birr per meter cube including transport cost around Akike quarry site.

Information regarding the method of transportation of natural sand from the river to the first point of use is not easily available. As all producers don't keep records of cost per m3 per km, the cost of transport for 1m3 of fine aggregate to a km distance is difficult to estimate or it will take a long process of data collection.

Natural sand material prices are expected to increase in the future due to the construction development and aspect of environmental effect used in the production and transporting processes. Construction work is currently growing fast and the cost is expected to affect the delivery prices of natural sand.

In Addis Ababa the purchase price of natural sand is increasing, by simply comparing the production cost of river sand and crushed sand it's advisable to use crushed sand as alternative sand.

Table 18 Natural sand cost on location

No.	Location	Distance from Addis Ababa (Km)	Sand purchasing cost(on place)	Transport cost In Birr	Others cost In birr	m^3	Total (birr) per 16 m3
1	Lanegano	198	2500	3000	2500	16	8000
2	Metehara	185	2500	3000	2500	16	8000
3	Meki	133	2500	2000	2000	16	7500
4	Alem tena	111	2500	1500	3000	16	7000
5	Welenchiti	114	2500	1500	2000	16	6000
6	Sodera	109	2500	1500	2000	16	6500

Table 19 Crushed sand cost on location

No.	Location	Distance from Addis Ababa (km)	m3	Total (birr)
1	Around Akike	5-7	16	6720-7500

CHAPTER - VI

5. Conclusion and Recommendations

5.1 Conclusion

The use of crushed sand in producing concrete was studied and the following conclusions were as below.

- ➔ Bulking of sand in the case of natural sand percentage is increasing but crushed sand is decrease.it better use for concrete is crushed sand.
- ➔ The workability of concrete manufactured with crushed sand was lesser than that manufactured with natural sand.
- ➔ Compressive strength at age of 7^{th}, 14^{th} and 28^{th} days is highest in case of crushed sand. Concrete with natural sand shows lower compressive strength of the concrete.
- ➔ The use of crushed sand in the construction industry helps to prevent unnecessary damages to the environment and also problems associated with extraction of natural sand will be solved.
- ➔ The cost of crushed sand is less that of natural sand. Hence crushed sand can be recommended to economical substitute for natural sand.

5.2 Recommendations

Based on the investigation made the following recommendations are forwarded;

- ➔ Concerned bodies should do more work regarding advertising this sand to create awareness. Because it has great economic benefit, high quality and makes construction works faster in around Addis Ababa.
- ➔ Considering, the acute shortage of river sand, huge short coming on quality of river sand, high cost, greater impact on environmental effects, The Construction Industry shall if start using the crushed sand to full extent as alternative, reduce the impacts on environment and economical effects.
- ➔ In concrete production in case of crushed sand use additives; since additives increase workability of concrete.
- ➔ The manufacturing process of manufactured sand requires active production control of all processes, storage should be dry and transportation has to be minimized to prevent segregation and cost too.

5.3 Future scope of work

- Replacing natural sand with different % of crushed sand so that clear variation of strength can be plotted as well as optimum amount can also be determined.
- Conducting investigation for M40, M50 and also for high strength concrete

References

[1] Dr. T Suresh Babu, M Anveshkumar, "An experimental investigation on the properties of," *International Journal of Applied Research,* vol. 2, no. 1, pp. 362-369, 2016.

[2] D. S. Robertson, The Future of Greek Studies, 2014.

[3] A. GETAHUN, Addis Ababa University, Faculty Of Technology, 2016.

[4] Rameshwar S. Ingalkar, Shrikant M. Harle, "Replacement of Natural Sand by Crushed Sand in the," *Landscape Architecture andRegional Planning.,* vol. 2, no. 1, 2017.

[5] "https://www.hunker.com/13425130/the-importance-of-sand-in-concrete," [Online].

[6] N. A.M., Properties of Concrete, Longman Scientific & Technical Series,, 5th edition. ed., 1986.

[7] S. Dinku, "THE USE OF MANUFACTURED SAND IN CONCRETE PRODUCTION: TEST RESULTS AND COST COMPARISON.," *Addis Ababa University Master's Thesis,* 2006.

[8] "https://nischinth.com/natural-sand-vs-manufactured-sand/," [Online].

[9] Elavenil, S.& Vijaya, B, "Manufactured sand, a solution and an alternative to river sand and in concrete manufacturing," *journal of engineering, computers & applied sciences,* vol. 2, no. 2, pp. 20-24, 2013.

[10] Rajendra P Mogre, Dr. Dhananjay K Parbat, Dr. Sudhir P Bajad, "Feasibility of Artificial Sand in Concrete," *International Journal of Engineering Research & Technology,* vol. 2, no. 7, pp. 1606-1610, 2013.

[11] Adams Joe M, Maria Rajesh A, Brightson P, Prem Anand M., "Experimental Investigation on the Effect of M-Sand in High Performance Concrete," *American Journal of Engineering Research.,* vol. 2, no. 12, pp. 46-51, 2013.

[12] Swastik S Shinde, Swanand R Kadam, Avinash A Waychal., "Experimental Study of Compressive Strength of Concrete with Partial Replacement of Natural Sand with Manufactured Sand,," *International Research Journal of Engineering and Technology,* vol. 3, no. 1, pp. 719-722, 2016.

[13] Harshlata R Raut, Ashish B Ugale, "Effect of Artificial Sand on Compressive Strength and Workability of Concrete," *International Journal of Engineering Research,* vol. 5, no. 3, pp. 673-674, 2016.

[14] Suresh S, Revathi J., "An Experimental Investigation of High Strength Concrete Using Manufacturing Sand," *International Journal of Advanced Engineering Technology,* vol. 3, no. 2, pp. 1112-1114, 2016.

[15] A. Dinku, "The Need for Standardization of Aggregates for Concrete Production in Ethiopian Construction Industry," in *Aggregate Conference*, addiss abab, May 2005.

[16] A. Dinku, Construction Materials - Labratory Manual, Addis Ababa University , 2002.

[17] A. C143, Slump of Hydraulic-Cement Concrete.

ANNEX A

Experimental procedures

A.1 Sample Concrete Mix Design Procedures, C-25 (ACI Method)

SUBMITTED BY :	Girma Hailu
PROJECT :	Research
SAMPLE OF:	**Natural Sand, C/Agg't - 02 & Cement Dangote OPC**
DATE SAMPLE :	===============
STATION :	===============
TEST REQUESTED:	**Concrete Mix Design, C-25 (ACI Method)**
REPORTED TO :	AASTU
	Reported On:

Input Data								
Class of Concrete :	C-25		Cement Sp. Gravity		3.15			
Cement Type:	OPC Dangote							
Required Cylindrical Compressive Strength	25	Mpa	3625	PSI				
Target Average Compressive Strength	4585	PSI	32	Mpa				
Required Slump	25-75	mm			**[From Table A 1.5.3.4 b, ACI]**			

Required Tests											
Fine Aggregate	Specific Gravity (Gs)	2.51	-	Clay Content of F/A			3.7	%		
	Water Absorption (WA)	3.31	%	Organic Impurti of F/A, ASTM Fig. No.			No . 2	-		
	Natural Moisture Content (NMC)	3.09	%							
	Fineness Modulus (FM)	2.57	-							
Coarse Aggregate	Specific Gravity (Gs)	2.79	-							
	Water Absorption (WA)	0.92	%							
	Natural Moisture Content (NMC)	0.70	%							
	Nominal Max. Size	37.5	mm							
	Dry Rodded Unit Weight	1617	Kg/m^3							

ACI Mix Design Process								
Step 1: Slump Required to be	25-75	mm						
Step 2: The aggregate to be used has a nominal maximum size of	37.5	mm						
Step 3: The concrete will be non-air entrained since the structure is not exposed to severe weathering. The estimated **mixing water** based on a slump and Aggregate size is found to be:	179	Kg/m3	Air	1.5	%	**[From Table A 1.5.3.3, ACI]**		
Step 4: The water-cement ratio for non-air entrained concrete with a given in the above strength is found :	0.5	m3	**[From Table A 1.5.3.4(a), ACI]**					
Step-5: From the information developed in Steps 3 and 4, the required **cement content** is found to be:	358	Kg/m3						
Step 6: The quantity of coarse aggregate is estimated from ACI Table. For a fine aggregate having a Fineness modulus and Nominal maximum size of coarse aggregate, the table indicates that:	0.72	m3	**[From Table A 1.5.3.6, ACI]**					
The Quantity of Coarse Aggregate	1164	Kg						
First Estimate of **Mass of Fresh Concrete**, by using Non air-entrained Concrete	2410	Kg/m3	**[From Table A 1.5.3.7.1, ACI]**					

Step 7: The Required Fine Aggregate may be determined on the basis of either Mass Basis or Absolute Volume Basis									
Mass Basis					Volume Basis				
Water(net mixing)		179.0	Kg		Volume of Water		0.1790	m3	
Cement		358.0	Kg		Volume of Cement		0.1137	m3	
Coarse Aggregate		1164.0	Kg		Volume of C/A		0.4177	m3	
Total		1701.0	Kg		Volume of Air		0.0150	m3	
					Total Volume of Ingredients Except F/A		0.7253	m3	
The Mass of Fine Aggregate to be:			709.0	Kg					
				Volume of Fine Aggregate Required				0.2747	m3
				Required Weight of dry F/A				688.8	Kg

Step 8: The Adjusted Aggregate Masses become											
	Coarse Aggregate (wet) :			1172.2	Kg			NMC C/A, %		0.705	
	Fine Aggregate (wet) :			730.9	Kg			NMC F/A, %		3.093	
Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water.											
					Absorption, C/A, %					0.9212	
					Absorption, F/A, %					3.3058	
					Absorption Minus NMC C/A, %					0.2163	
					Absorption Minus NMC F/A, %					0.213	
Based on absolute Volume of Ingredients											
						Correction in Water		Additional Water			W/C
		Water		180.0	Lit/m3	180.0	5	0	lt		0.5028
		Cement		358.0	Kg/m3						
		Sand or F/A		730.9	Kg/m3						
		Coarse Aggregate, C/A		1172.2	Kg/m3						

Step 9, Adjusted for Lab. Batch				0.027	m3				
		Water		4.86	Lit				
		Cement		9.67	Kg				
		Sand or F/A		19.74	Kg				
		Coarse Aggregate, C/A		31.65	Kg				
		Additive			ml	Additive in		0	% or
		Slump achieved during test			mm			0	Ml
	Volume of Cube Size 15x15 =				0.00338	m3			
	Weight of Fresh Concrete + Mould						Kg		
	Weight of Mould						Kg		
	Weight of Fresh Concrete						Kg		
	Unit Weight of Fresh Concrete						Kg/m3		

SUBMITTED BY : Girma Hailu
PROJECT : Research
SAMPLE OF: **Crushed Fine, C/Agg't - 02 & Cement Dangote OPC**
DATE SAMPLE : ===============
STATION : ===============
TEST REQUESTED: **Concrete Mix Design, C-25 (ACI Method)**
REPORTED TO : AASTU
Reported On:

Input Data								
Class of Concrete :	C-25		Cement Sp. Gravity		3.15			
Cement Type:	OPC Dangote							
Required Cylindrical Compressive Strength	25	Mpa	3625	PSI				
Target Average Compressive Strength	4585	PSI	32	Mpa				
Required Slump	25-75	mm			**[From Table A 1.5.3.4 b, ACI]**			

Required Tests											
Fine Aggregate	Specific Gravity (Gs)	2.81	-	Clay Content of F/A			4.5	%			
	Water Absorption (WA)	3.31	%	Organic Impurti of F/A, ASTM Fig. No.			No. 1	-			
	Natural Moisture Content (NMC)	3.09	%								
	Fineness Modulus (FM)	2.99	-								
Coarse Aggregate	Specific Gravity (Gs)	2.79	-								
	Water Absorption (WA)	0.92	%								
	Natural Moisture Content (NMC)	0.70	%								
	Nominal Max. Size	37.5	mm								
	Dry Rodded Unit Weight	1617	Kg/m^3								

ACI Mix Design Process								
Step 1: Slump Required to be	25-75	mm						
Step 2: The aggregate to be used has a nominal maximum size of	37.5	mm						
Step 3: The concrete will be non-air entrained since the structure is not exposed to severe weathering. The estimated **mixing water** based on a slump and Aggregate size is found to be:	193	Kg/m3	Air	1.5	%	**[From Table A 1.5.3.3, ACI]**		
Step 4: The water-cement ratio for non-air entrained concrete with a given in the above strength is found :	0.52	m3	**[From Table A 1.5.3.4(a), ACI]**					
Step-5: From the information developed in Steps 3 and 4, the required **cement content** is found to be:	371	Kg/m3						
Step 6: The quantity of coarse aggregate is estimated from ACI Table. For a fine aggregate having a Fineness modulus and Nominal maximum size of coarse aggregate, the table indicates that:	0.72	m3	**[From Table A 1.5.3.6, ACI]**					
The Quantity of Coarse Aggregate	1164	Kg						
First Estimate of **Mass of Fresh Concrete**, by using Non air-entrained Concrete	2410	Kg/m3	**[From Table A 1.5.3.7.1, ACI]**					

Step 7: The Required Fine Aggregate may be determined on the basis of either Mass Basis or Absolute Volume Basis									
Mass Basis					Volume Basis				
Water(net mixing)		193.0	Kg		Volume of Water		0.1930	m3	
Cement		371.2	Kg		Volume of Cement		0.1178	m3	
Coarse Aggregate		1164.0	Kg		Volume of C/A		0.4177	m3	
Total		1728.2	Kg		Volume of Air		0.0150	m3	
					Total Volume of Ingredients Except F/A		0.7435	m3	
The Mass of Fine Aggregate to be:			681.8	Kg					
				Volume of Fine Aggregate Required				0.2565	m3
				Required Weight of dry F/A				720.8	Kg

Step 8: The Adjusted Aggregate Masses become								
Coarse Aggregate (wet) :	1172.2	Kg			NMC C/A, %		0.70	
Fine Aggregate (wet) :	702.9	Kg			NMC F/A, %		3.09	
Absorbed water does not become part of the mixing water and must be excluded from the adjustment in added water.								
		Absorption, C/A, %					0.9212	
		Absorption, F/A, %					3.31	
		Absorption Minus NMC C/A, %					0.2163	
		Absorption Minus NMC F/A, %					0.2172	
Based on absolute Volume of Ingredients								
			Correction in Water		Additional Water			W/C
Water	194.0	Lit/m3	194.0	5	0	lt		0.52
Cement	371.2	Kg/m3						
Sand or F/A	702.9	Kg/m3						
Coarse Aggregate, C/A	1172.2	Kg/m3						

Step 9, Adjusted for Lab. Batch			0.027	m3				
		Water	5.24	Lit				
		Cement	10.02	Kg				
		Sand or F/A	18.98	Kg				
		Coarse Aggregate, C/A	31.65	Kg				
		Additive		ml	Additive in		0	% or
		Slump achieved during test		mm			0	Ml
	Volume of Cube Size 15x15 =			0.00338	m3			
	Weight of Fresh Concrete + Mould					Kg		
	Weight of Mould					Kg		
	Weight of Fresh Concrete					Kg		
	Unit Weight of Fresh Concrete					Kg/m3		

A.2 Bulking of fine Aggregate

A.2.1 Objective

- To study the amount of surface moisture in fine aggregate by displacement in water.

A.2.2 Equipment used

- Sample of moist sand
- Graduated cylinder
- Clean water
- Small size spoon and
- Calculator.

A.2.3 Theory

It is an apparent increase in the volume of sand due to the presence of moisture. So, It is expressed as the percentage of original dry volume. The extent of bulking depends on the amount of moisture and finesse of sand. Hence, it increases with increases of moisture content up to a certain limit. And beyond that, further increase of moisture content in the volume at saturation point, there is no sign of bulking.

Due to the bulking phenomenon, the quantity of sand proportion would be always less than the actual requirement. Therefore, the effect of bulking can be compensated by taking of the extra volume of sand equal to the extent of bulking. Fine sand exhibits more bulking than coarse sand for the same moisture content. The tests on the determination of Bulking of Sand involve in the determination of the % bulk gradient in the sand at any instant of time.

A.2.4 Procedure

1. Take200 ml of sand in measuring jar and take the weight of sand
2. Add water is one percentage of the weight(sand) and mixed thoroughly and measure the increasing volume
3. Add 2%,3%,4%..........and the process is repeated for a number of times and each increase in volume is taken
4. After the increase in volume there is a slow decrease in volume, then pure water is added to the sand to increase it that will give original volume
5. When water added the volume of sand increased and an optimum volume of sand reached
6. A graph is plotted by taking the percentage of increase in volume and percentage of bulking

A.2.5 Calculation

- Percentage of bulking of sand $= \frac{V-Va}{Va} x100$

Where: -

- V=Volume of bulked sand
- Va=Actual volume of sand

A.3 Specific Gravity and Water Absorption of fine Aggregate

A.3.1 Objective

- To determination of specific gravity & water absorption of aggregates.

A.3.2 Equipment used

- Balance of capacity about 0.5g-3kg
- A thermostatically controlled oven to maintain temperature at 100-110° C.
- A wire basket of not more than 6.3 mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.
- A container for filling water and suspending the basket
- An airtight container of capacity similar to that of the basket
- A shallow tray and two absorbent cloths, each not less than 75x45cm.

A.3.3 Theory

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. The stones having low specific gravity are generally weaker than those with higher specific gravity values.

A.3.4 Procedure

1. About 2 kg of aggregate sample is washed thoroughly to remove fines, drained and placed in wire basket and immersed in distilled water at a temperature between 22- 32º C and a cover of at least 5cm of water above the top of the basket.
2. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop at the rate of about one drop per second. The basket and aggregate should remain completely immersed in water for a period of 24 hours afterwards.
3. The basket and the sample are weighed while suspended in water at a temperature of 22° – 32°C. The weight while suspended in water is noted =W1g.
4. The basket and aggregates are removed from the water and allowed to drain for a few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is then returned to the tank of water jolted 25 times and weighed in water=W2g. .

5.The aggregates placed on the absorbent clothes are surface dried till no further moisture could be removed by this cloth. Then the aggregates transfer to the second dry cloth spread in single layer and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. The surface dried aggregate is then weighed =W3 g

6.The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110° C for 24 hrs. It is then removed from the oven, cooled in an airtight container and weighted=W4 g.

a) Specific gravity = (dry weight of the aggregate /Weight of equal volume of water)
b) Apparent specific gravity = (dry weight of the aggregate/Weight of an equal volume of water excluding air voids in aggregate)

A.3.5 Calculation

(1) Specific gravity = W3 / (W3– (W1– W2))

(2) Apparent specific gravity = W4 / (W4– (W1– W2))

Where: -

Weight of saturated aggregate suspended in water with basket = W1 g

Weight of basket suspended in water = W2 g

Weight of saturated aggregate in water = W1 – W2 g

Weight of saturated surface dry aggregate in air = W3 g

Weight of water equal to the volume of the aggregate = W3–(W1–W2) g

Weight of oven dry aggregate = W4 g

A.4 Unit Weight of Fine Aggregate

A.4.1 Objective

TO determine the unit weight(bulk density) and voids of aggregate in compacted and loose condition.

A.4.2 Equipment used

- Balance - Sensitive to 0.5% by weight of material
- Cylindrical metal measure
    - 03 liter capacity (for fine aggregate)
    - 15 liter capacity for aggregate greater than 4.75mm and up to 40mm
    - 30-liter capacity for aggregate more than 40mm
- Tamping rod 16 mm dia and 60 cm long a cylindrical metal measure used for bulk density and void test for aggregate

A.4.3 Theory

Take the required amount of test sample from the bulk sample using any sample reduction method. The test is normally carried out on dry material, but when bulking tests are required, material with a given percentage of moisture may be used.

A.4.4 Procedure

I. PROCEDURE FOR COMPACTED BULK DENSITY

1. Measure the volume of the cylindrical metal measure (three times for average) by pouring water into the metal measure and record the volume “V” in liters.
2. Fill the cylindrical metal measure about one-third full with thoroughly mixed aggregate and tamp it 25 times using tamping bar.
3. Add another layer of one-third volume of metal measure and give another 25 strokes by tamping bar.
4. Finally, fill aggregate in the metal measure to over-flowing and tamp it 25 times.
5. Remove the surplus aggregate using the tamping rod as a straight edge.
6. Determine the weight of the aggregate in the measure and record that weight “W” in kg.

II. PROCEDURE FOR LOOSE BULK DENSITY

1. Measure the volume of the cylindrical metal measure (three times for average) by pouring water into the metal measure and record the volume “V” in litre.
2. Fill the cylindrical measure to overflowing by means of a scoop, the aggregate being discharged from a height not exceeding 5 cm above the top of the measure
3. Level the top surface of the aggregate in the metal measure, with a straight edge or tamping bar.
4. Determine the weight (three times for average) of the aggregate in the measure and record the weight “W” in kg.

A.4.5 Calculation

1. Compacted unit weight or bulk density = W / V
   - Where,
   - W = Average Weight of compacted aggregate in cylindrical metal measure, kg
   - V = Average Volume of cylindrical metal measure, liter
2. Loose unit weight or bulk density = W / V
   - Where,
   - W = Weight of loose aggregate in cylindrical metal measure, kg
   - V = Volume of cylindrical metal measure, liter

A.5 Gradation test for Fine Aggregates

A.5.1 Objective

- The Standard grain size analysis test determines the relative proportions of different grain sizes as they are distributed among certain size ranges.

A.5.2 Equipment used

- Stack of Sieves including pan and cover
- Balance (with accuracy to 0.01 g)
- Rubber pestle and Mortar (for crushing the soil if lumped or conglomerated)
- Mechanical sieve shaker
- Oven

A.5.3 Theory

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

A.5.4 Procedure

1. take a representative oven dried sample of soil that weighs about 500 g. (this is normally used for soil samples the greatest particle size of which is 4.75 mm)
2. If soil particles are lumped or conglomerated crush the lumped and not the particles using the pestle and mortar.
3. Determine the mass of sample accurately. Wt (g)
4. Prepare a stack of sieves. Sieves having larger opening sizes (i.e lower numbers) are placed above the ones having smaller opening sizes (i.e higher numbers). The very last sieve is #200 and a pan is placed under it to collect the portion of soil passing #200 sieve. Here is a full set of sieves. (#s 4 and 200 should always be included)

Table 20 sieve number and size

Sieve number	Opening size(mm)
4	**4.750**
6	**3.350**
8	**2.360**
12	**1.680**
16	**1.180**
20	**0.850**
30	**0.600**
40	**0.425**
50	**0.300**
60	**0.250**
80	**0.180**
100	**0.150**
140	**0.106**
200	**0.075**
270	**0.053**

5.

6. Make sure sieves are clean, if many soil particles are stuck in the openings try to poke them out using brush.
7. Weigh all sieves and the pan separately. (Fill in column 3)
8. Pour the soil from step 3 into the stack of sieves from the top and place the cover, put the stack in the sieve shaker and fix the clamps, adjust the time on 10 to 15 minutes and get the shaker going.

9. Stop the sieve shaker and measure the mass of each sieve + retained soil. (fill in column 4)

Table 21 sieve analsis

1	2	3	4	5	6	7	8
sieve #	Sieve size (mm)	Mass of each sieve (mm)	Mass of each sieve + retained soil	Mass of soil retained-Wn(g) Col 4- Col 3	Percentage on each sieve Rn Col 5/Wt*100	Cumulative percent retained Rn	% finer,100-∑Rn
4	4.75						
8	2.36						
16	1.18						
30	0.6						
40	0.425						
50	0.3						
100	0.15						
200	0.075						
pan				∑=W1=			

A.5.5 Calculation

A. Column 5 = Column4 - Column3
B. Column 6 = Column5 / (Total mass in step 3)
C. Calculate the cumulative percent of soil retained on the nth sieve,
   = ∑ Rn
D. Calculate the cumulative percent passing through the nth sieve,
   = Percent finer = 100 - ∑ Rn or 100 - Column 7

A.6 Workability or Slump test

A.6.1 Objective

- The concrete slump test is to determine the workability or consistency of a concrete mix, prepared in the laboratory or the construction site during the progress of the work. [17]

A.6.2 Equipment used

- Standard slump cone (100 mm top diameter x 200 mm bottom diameter x300 mm high)
- Bullet-nosed rod (600mm long x 16 mm diameter)
- Slump plate (500 mm x500 mm
- Small scoop
- Ruler
- Weighing machine

A.6.3 Theory

Concrete is tested during its fresh and harden state mainly to ensure that the concrete mix satisfies the specification of works. In its fresh state, concrete is tested for its consistency so as to achieve the desired workability. Workability is an important property in concrete since a workable mix will produce concrete, which can be well compacted, transported and placed without segregation. A well

Compacted concrete will produce a good strength concrete. Unsupported concrete, when it is fresh, will flow to the site and sinking in height will take place. This vertical settlement is known as a slump. In this test fresh concrete is filled into a mold of specified shape and the settlement or slump is measured when the supporting mold is removed. Slump increases as water cement ratio increases and for different work different slump values are suitable.

A.6.4 Procedure

1. Clean the internal surface of the mold and apply oil.
2. Place the mold on a smooth horizontal non- porous base plate.
3. Fill the mold with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mold. For the subsequent layers, the tamping should penetrate into the underlying layer.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mold and the base plate.
7. Raise the mold from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mold and that of height point of the specimen being tested.

NOTE:

The above operation should be carried out at a place free from Vibrations or shock and within a period of 2 minutes after sampling.

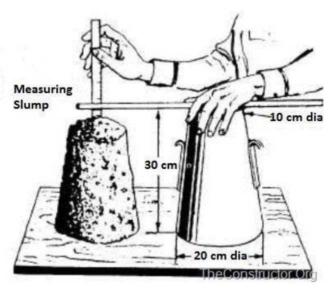


Figure 9 Measuring Slump of Concrete

When the slump test is carried out, following are the shape of the concrete slump that can be observed:

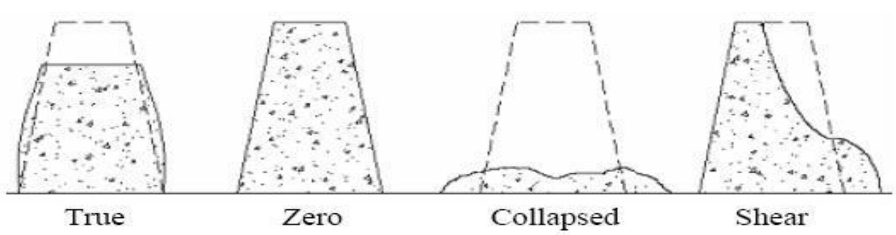


Figure 10 Types of Concrete Slump Test Results

- True Slump – True slump is the only slump that can be measured in the test. The measurement is taken among the top of the cone and the top of the concrete after the cone has been removed as shown in figure-1.
- Zero Slump – Zero slump is the indication of very low water-cement ratio, which results in dry mixes. These types of concrete are generally used for road construction.
- Collapsed Slump – This is an indication that the water-cement ratio is too high, i.e. concrete mix is too wet or it is a high workability mix, for which a slump test is not appropriate.
- Shear Slump – The shear slump indicates that the result is incomplete, and concrete to be retested.

Table 22 different ranges of slump values and how they might be used.

Degree of Workability	**Slump, in (mm)**	**Application**
Very low	0-1 (0-25)	Very dry mixes used in paving machines with high-powered vibration
Low	1-2 (25-50)	Low-workability mixes used for foundations with light reinforcement; Pavements consolidated by hand-operated vibrators
Medium	2-4 (50-100)	Medium workability mixes; manually consolidated flat slabs. Normal reinforced concrete manually placed; heavily reinforced sections with mechanical vibration
High	4-7 (100-175)	High workability concrete for sections with congested reinforcement; May not respond well to vibration

A.7 Compressive Strength test

A.7.1 Objective

- The tests are required to determine the strength of concrete and therefore its suitability for the job.

A.7.2 Equipment used

- 150 mm Cube Molds (with IS Mark)
- Electronic Weighing Balance
- G.I Sheet (For Making Concrete)
- Vibrating Needle & other tools
- Compressions Testing Machine

A.7.3 Theory

- **Age at Test -** Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may be made at the ages of 24 hours ±½ hour and 72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to the dry ingredients.
- **Number of Specimens -** At least three specimens, preferably from different batches, shall be made for testing at each selected age.

A.7.4 Procedure

1. Sampling of Materials - Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.
2. Proportioning - The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.
3. Weighing - The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

4. Mixing Concrete - The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after molding the desired number of test specimens.
5. Mold - Test specimens cubical in shape shall be 15 × 15 × 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10 cm cubes may be used as an alternative. Cylindrical test specimens shall have a length equal to twice the diameter.
6. Compacting - The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive latency.
7. Curing - The test specimens shall be stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27° ± 2°C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients.
8. Placing the Specimen in the Testing Machine - The bearing surfaces of the testing machine shall 64 be wiped clean and any loose sand or other material removed from the surfaces of the specimen which are to be in contact with the compression platens.
9. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom.
10. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine.
11. The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.
12. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted

A.7.5 Calculation

Table 23 mix proportion of concrete format

Mix proportion of concrete	For 1 cubic meter of concrete	For one batch of mixing
Coarse aggregate (kg)		
Fine aggregate (kg)		
Cement (kg)		
Water (kg)		
S/A		
w/c		
Admixture		

Table 24 compressive strength of concrete result format

Sr. No.	Age of Cube	Weight of Cement Cube (gms)	Cross-Sectional area (mm^2)	Load (N)	Compressive strength (N/mm^2)	Average Compressive strength (MPa)
1	7 Days					
2						
3						
4	28 Days					
5						
6						

$$\text{Compressive Strength of concrete} = \frac{\text{Maximum compressive load}}{\text{cross sectikn area}}$$

A.8 Water absorption

A.8.1 Objective

A. To determine the water absorption capacity of concrete

A.8.2 Equipment used

B. Drying Oven
C. Immersion Tank
D. Balance (0-10 kg)

A.8.3 Theory

The weight of a quantity of water absorbed to the weight of concrete expressed as a percentage is the water absorption capacity of a concrete. The strength of concrete depends upon its water absorption capacity. As we know that, the water absorption is due to the presence of voids in the concrete. If the concrete has more voids it has a chance to absorb more water, reducing the load carrying capacity. Hence, we should test the concrete before using them in construction work.

A.8.4 Procedure

E. Dry the specimen in a ventilated oven at a temperature of 105 °C to 115°C till it attains substantially constant mass.
F. Cool the specimen to room temperature and obtain its weight (M1) specimen too warm to touch shall not be used for this purpose.
G. Immerse completely dried specimen in clean water at a temperature of 27+2°C for 24 hours.
H. Remove the specimen and wipe out any traces of water with damp cloth and weigh the specimen after it has been removed from water (M2).

A.8.5 Calculation of Water Absorption of concrete

- Water absorption, % by mass, after 24 hours immersion in cold water in given by the formula,

$$\%\ \text{water absorption} = \frac{\text{W2} - \text{W1}}{\text{W1}}\ X\ 100$$

ANNEX B

Test Results

B.1 Bulk of sand Test result

A. Natural sand

Table 25 Bulk of sand test for Natural sand

S.NO.	SAMPLE NO.	SAMPLE NO.		
		I	II	III
1	Volume of loose sand.ml	200	200	200
2	Volume of saturated sand(Y),ml	154	158	155
3	$Percent\ of\ bulking\ = \frac{200-Y}{Y}$ X 100,%	29.9	26.6	29.0
4	Average value,%	**28.49**		

B. Crushed Sand

Table 26 Bulk of sand test for crushed sand

S.NO.	SAMPLE NO.	SAMPLE NO.		
		I	II	III
1	Volume of loose sand.ml	200	200	200
2	Volume of saturated sand(Y),ml	160	165	168
3	$Percent\ of\ bulking\ = \frac{200-Y}{Y}$ X 100,%	25.0	21.2	19.0
4	Average value,%	**21.75**		

B.2 Specific Gravity and Water Absorption

A. Natural sand

Table 27: TEST METHOD: AASHTO T 84-91, T85 or ASTM C117-90

No.			Test 1	Test 2
1	Flask Number		0	0
2	Weight of Flask (g)		0	0
3	Weight of Flask + SSD Test Sample (g)		0	0
4	Weight of SSD Test Sample (g)	**S**	500	500
5	Weight of oven dry test sample (g)	**A**	484	484
6	Weight of flask + full of water (gm)	**B**	1654	1654
7	Weight of flask + Sampl + full of water (gm)	**C**	1961.0	1961
8	Volume of Sample (4+6)-7		193	193
9	Specific Gravity SSD test Sample (3/7) or S/(B+S-C)		2.591	2.591
10	**Average Specific Gravity SSD**		**2.591**	
11	Bulk Specific Gravity (dry basis) = (Sp.Gr. SSD)/(100+ % Abs))*100		2.508	2.508
12	**Average Bulk Specific Gravity (dry basis)**		**2.508**	
13	Apparent Specific Gravity of test Sample A/(B+A-C)		2.825	2.825
14	**Average Apparent Specific Gravity of test Sample**		**2.825**	
15	Water Absorption of test ((4-5)/5)100		3.306	3.306
16	**Average Water Absorption of test**		**3.31**	
17	NMC Determination			
18	Weight of test sample Befor Oven Dry (gm)		500	500
19	Weight of test sample After Oven Dry (gm)		485	485
20	Natural Moisture Content ((15-16)/16)*100		3.093	3.093
21	**Average Natural Moisture Content, %**		**3.093**	
22	Absorption Minus NMC (%)		0.213	0.213

Specific Gravity	**SSD**	**2.59**
	Bulk	**2.51**
	Apparent	**2.82**

Absorption,%	**3.31**
NMC, %	**3.09**

B. Crushed sand

Table 28: TEST METHOD: AASHTO T 84-91, T85 or ASTM C117-90

No.			Test 1	Test 2	
1	Flask Number		0	0	
2	Weight of Flask (g)		0	0	
3	Weight of Flask + SSD Test Sample (g)		0	0	
4	Weight of SSD Test Sample (g)	**S**	500	500	
5	Weight of oven dry test sample (g)	**A**	484	484	
6	Weight of flask + full of water (gm)	**B**	1654	1654	
7	Weight of flask + Sampl + full of water (gm)	**C**	1976.2	1976.2	
8	Volume of Sample (4+6)-7		177.78	177.78	
9	Specific Gravity SSD test Sample (3/7) or S/(B+S-C)		2.812	2.812	
10	**Average Specific Gravity SSD**		**2.812**		
11	Bulk Specific Gravity (dry basis) = (Sp.Gr. SSD)/(100+ % Abs))*100		2.722	2.722	
12	**Average Bulk Specific Gravity (dry basis)**		**2.722**		
13	Apparent Specific Gravity of test Sample A/(B+A-C)		3.091	3.091	
14	**Average Apparent Specific Gravity of test Sample**		**3.091**		
15	Water Absorption of test ((4-5)/5)100		3.306	3.306	
16	**Average Water Absorption of test**		**3.31**		
17	NMC Determination				
18	Weight of test sample Befor Oven Dry (gm)		500	500	
19	Weight of test sample After Oven Dry (gm)		485	485	
20	Natural Moisture Content ((15-16)/16)*100		3.093	3.093	
21	**Average Natural Moisture Content, %**		**3.093**		
22	Absorption Minus NMC (%)		0.213	0.213	

Specific Gravity	**SSD**	**2.720**
	Bulk	**2.810**
	Apparent	**2.990**

Absorption,%	**3.31**
NMC, %	**3.09**

B.3 Unit Weight of Fine Aggregate Test result

A. Natural sand

Table 29: TEST METHOD AASHTO T-019-93 for Natural sand

(a) Fine Aggregate (LOOSE)						
TEST METHOD AASHTO T-019-93						
Sr. No	**Wt. of Mould, gm**	**Wt. of Mould + Sample, gm**	**Wt. of Sample, gm**	**Volume of Mould, Cm^3**	Unit Weight, Kg/m^3	Average
1	3.05	7	3.95	0.003	1316.67	1317
2		7	3.95		1316.67	
3		7	3.95		1316.67	
(b) Fine Aggregate (COMPACTED)						
TEST METHOD AASHTO T-019-93						
Sr. No	**Wt. of Mould, gm**	**Wt. of Mould + Sample, gm**	**Wt. of Sample, gm**	**Volume of Mould, Cm^3**	Unit Weight, Kg/m^3	Average
1	3.05	7.2	4.15	0.003	1383.33	1383
2		7.2	4.15		1383.33	
3		7.2	4.15		1383.33	

B. Crushed sand

Table 30: TEST METHOD AASHTO T-019-93 for Crushed sand

a) **Fine Aggregate (LOOSE)**

TEST METHOD AASHTO T-019-93

Sr. No	**Wt. of Mould, gm**	**Wt. of Mould + Sample, gm**	**Wt. of Sample, gm**	**Volume of Mould, Cm^3**	**Unit Weight, Kg/m^3**	**Average**
1	3.05	7.3	4.25	0.003	1416.67	
2		7.3	4.25		1416.67	**1417**
3		7.3	4.25		1416.67	

b) **Fine Aggregate (COMPACTED)**

TEST METHOD AASHTO T-019-93

Sr. No	**Wt. of Mould, gm**	**Wt. of Mould + Sample, gm**	**Wt. of Sample, gm**	**Volume of Mould, Cm^3**	Unit Weight, Kg/m^3	Average
1	3.05	7.8	4.75	0.003	1583.33	
2		7.8	4.75		1583.33	1583
3		7.8	4.75		1583.33	

B.4 Gradation test for Fine Aggregates Test result

A. Natural sand

Table 31: Gradation test for Coarse & Fine Aggregates

Nº	Sieve size (mm)	% pass			Graduation requirement % pass(ASTM C33)		
		Sand	Coarse Aggregate				
			25 mm	30mm	Sand	25 mm	30mm
1	75						
2	63						
3	50		100				
4	37.5		99			100	
5	25		81			90 - 100	
6	19		55			40 - 85	
7	12.5	100	32			10 - 40	
8	9.5	100	12		100	0 - 15	
9	4.75	97	1		95 - 100	0 - 5	
10	2.36	95			80 - 100		
11	1.18	83			50 - 85		
12	0.6	50			25 - 60		
13	0.3	13			10 - 30		
14	0.15	5			2 - 10		
15	0.075	-					
	FM	**2.57**					

Table 32: Quality test

Nº	Test type	Test result		Max allowable Requirement (ASTM C33)
		Sand	Coarse Agg.	
2.1	Material Finer than No 200 (AASHTO T-11)	3.73	-	Max 5%
2.2	Clay Lumps & Friable Particles (%) (ASTM C 142)	-	-	Max.ASTM C33 3%
2.3	Organic impurity Plate No. (AASHTO T-21)	No. 2	-	Max Plate N^{O} 3
2.4	Bulk Specific Gravity (AASHTO T-84 & T-85)	2.51	2.79	
2.5	Bulk Specific Gravity (SSD) (AASHTO T-84 & T-85)	2.59	2.81	
2.6	Specific Gravity apparent (AASHTO T-84 & T-85)	2.82	2.86	
2.7	Water Absorption (%) (AASHTO T-84 & T-85)	3.31	0.92	
2.8	Unit weight Loose Kg/m^3 (AASHTO T-19)	1317	1455	
2.9	Unit weight Compact Kg/m^3 (AASHTO T-19)	1383	1617	

B. Crushed sand

Table 33: Gradation test for Coarse & Fine Aggregates

		% pass			Graduation requirement		
No.	Sieve		Coarse Aggregate		% pass(ASTM C33)		
	size (mm)	Sand	25 mm	30mm	Sand	25 mm	30mm
1	75						
2	63						
3	50		100				
4	37.5		99			100	
5	25		81			90 - 100	
6	19		55			40 - 85	
7	12.5	100	32			10 - 40	
8	9.5	100	12		100	0 - 15	
9	4.75	97	1		95 - 100	0 - 5	
10	2.36	76			80 - 100		
11	1.18	54			50 - 85		
12	0.6	41			25 - 60		
13	0.3	21			10 - 30		
14	0.15	12			2 - 10		
15	0.075	-					
	FM	2.99					

Table 34: Quality test

Nº	Test type	Test result		Max allowable Requirement (ASTM C33)
		Sand	Coarse Agg.	
2.1	**Material Finer than No 200 (AASHTO T-11)**	4.53	-	Max 5%
2.2	**Clay Lumps & Friable Particles(%) (ASTM C 142)**	-	-	Max.ASTM C33 3%
2.3	**Organic impurity Plate No. (AASHTO T-21)**	No. 1	-	Max Plate no. 3
2.4	**Bulk Specific Gravity (AASHTO T-84 & T-85)**	2.81	2.79	
2.5	**Bulk Specific Gravity (SSD) (AASHTO T-84 & T-85)**	2.72	2.81	
2.6	**Specific Gravity apparent (AASHTO T-84 & T-85)**	2.99	2.86	
2.7	**Water Absorption (%) (AASHTO T-84 & T-85)**	3.31	0.92	
2.8	**Unit weight Loose Kg/m^3 (AASHTO T-19)**	1417	1455	
2.9	**Unit weight Compact Kg/m^3 (AASHTO T-19)**	1583	1617	

B.5 Workability or Slump Test result

Table 35 workability of concrete results

Mix proportion	Slump value (mm)	
Grade(Mpa)	Natural sand	Crushed sand
C-20	100	85
C-25	80	75
C-30	45	35

B,6 Compressive Strength Test result

A. Natural sand

Table 36: Compressive Strength Test for 7 days

Marking	Date		Age in Days	Dimension - m			Unit Weight, Kg/m^3	Compressive Strength	
	Poured	Tested		L	W	H		Map	PSI
1	1/1/2018	8/1/2018	7	0.15	0.15	0.15	2607	18.89	2739
2	1/1/2018	8/1/2018	7	0.15	0.15	0.15	2637	17.69	2565
3	1/1/2018	8/1/2018	7	0.15	0.15	0.15	2667	18.44	2674

Table 37: Compressive Strength Test for 28 days

Marking	Date		Age in Days	Dimension - m			Unit Weight, Kg/m^3	Compressive Strength	
	Poured	Tested		L	W	H		Map	PSI
1	1/1/2018	29/1/2018	28	0.15	0.15	0.15	2607	29.87	4331
2	1/1/2018	29/1/2018	28	0.15	0.15	0.15	2637	29.16	4228
3	1/1/2018	29/1/2018	28	0.15	0.15	0.15	2667	31.20	4524

B. Compressive Strength Test of Crushed sand

Table 38: Compressive Strength Test for 7 days

Marking	Date		Age in Days	Dimension - m			Unit Weight, Kg/m^3	Compressive Strength	
	Poured	Tested		L	W	H		Map	PSI
1	1/1/2018	8/1/2018	7	0.15	0.15	0.15	2637	20.00	2900
2	1/1/2018	8/1/2018	7	0.15	0.15	0.15	2607	20.89	3029
3	1/1/2018	8/1/2018	7	0.15	0.15	0.15	2607	20.80	3016

Table 39: Compressive Strength Test for 28 days

Marking	Date		Age in Days	Dimension - m			Unit Weight, Kg/m^3	Compressive Strength	
	Poured	Tested		L	W	H		Map	PSI
1	1/1/2018	29/1/2018	28	0.15	0.15	0.15	2637	33.96	4924
2	1/1/2018	29/1/2018	28	0.15	0.15	0.15	2607	33.11	4801
3	1/1/2018	29/1/2018	28	0.15	0.15	0.15	2607	34.31	4975

B.7 Water absorption Test result

Table 40: Water absorption Test for 7 days

Material	7 days			
	Sample	Dry weight in grams (W1)	Wet weight in grams (W2)	% water absorption
Natural Sand	sampe-1	8400	8750	4%
	Samp-2	8350	8800	5%
	Sampe-3	8300	8850	7%
Crushed Sand	sampe-1	8900	8150	9%
	sampe-2	8800	8200	7%
	sampe-3	8850	8250	7%

Table 41: Water absorption Test for 28 days

Material	28 days			
	sample	Dry weight in grams (W1)	Wet weight in grams (W2)	% water absorption
Natural Sand	sampe-1	8800	8400	5%
	sampe-2	9000	8650	4%
	sampe-3	8900	8300	7%
Crushed Sand	sampe-1	8900	8150	9%
	sampe-2	8800	8300	6%
	sampe-3	8800	8350	5%

ANNEX C

Sample Photo Gallery Taken During the Study

Figure 11: sample of sand for bulking test

Figure 12: Insert the sand and mix with cylindrical cones

Figure 13:sand balance and wishing

Figure 14: sample balance and mix

Figure 13: concrete mix and slump test

Figure 14: molding and casting

Figure 15: curing and balance

Figure 16 compressive strength test machines